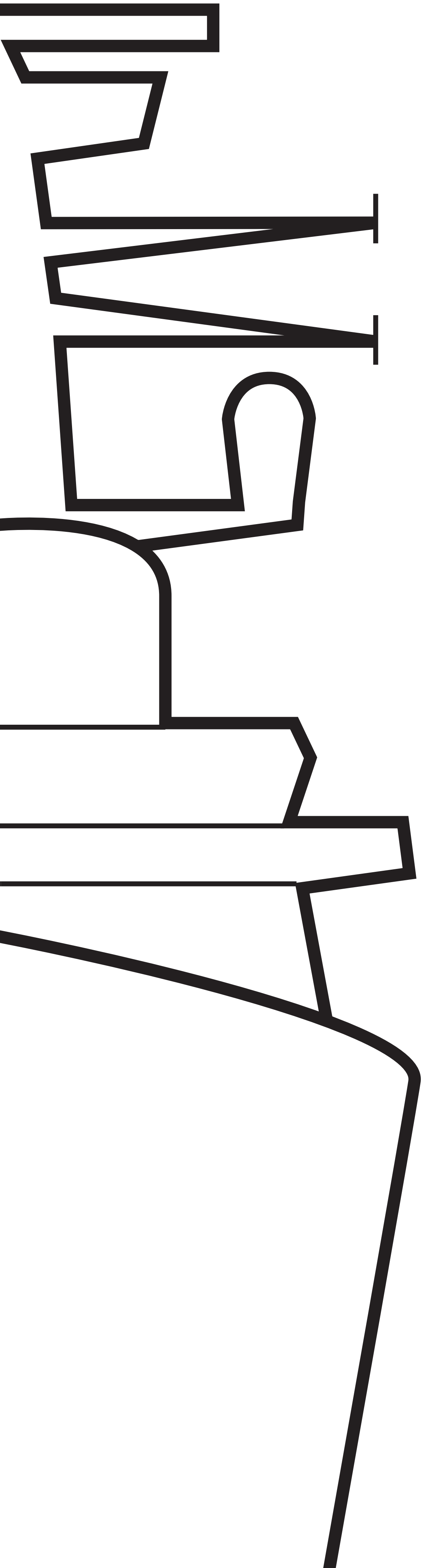

Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 1*

Regulations

January 2005

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda. A dot-dash line indicates changes necessitated by International Conventions, Code of Practice or IACS Unified Requirements.

Rules programs

LR has developed windows based Rules Calculation Software which evaluates Rule Requirements for Special Service Crafts' structures. For details of this software please contact Lloyd's Register.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to Lloyd's Register's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2005

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■ *Section 1*

1.1 Lloyd's Register (hereinafter referred to as LR), which is recognized under the laws of the United Kingdom as a Corporation whose business is conducted for the benefit of the community, was founded in 1760. It was established for the purpose of obtaining for the use of Merchants, Shipowners and Underwriters a faithful and accurate Classification of Merchant Shipping and whilst it still continues to fulfil that purpose, it now also:

(a) approves design, surveys and reports on: hovercraft; ships which embody features of a novel kind; non-mercantile shipping; yachts; amphibious and land and sea and sea bed installations, structures, plant, etc.; machinery, apparatus, materials, components, equipment, production methods and processes of all kinds; for the purpose of testing their compliance with plans, specifications, Rules, Codes of Practice, etc., or their fitness for particular requirements;

(b) acts with delegated authority on behalf of numerous governments in respect of Statutory Requirements;

(c) provides other technical inspection and advisory services relating to ships and the maritime industry generally and also in respect of land and sea-based undertakings.

■ *Section 2*

2.1 LR's affairs are under the overall direction of the General Committee, which is composed of persons nominated or elected to represent the world community and industry which LR serves.
The General Committee (hereinafter referred to as the Committee), which may at its discretion vary the constitution of such representation, is currently composed of:

- The Corporation of Lloyd's (five representatives).
- The International Underwriting Association (two representatives).
- The Chamber of Shipping (five representatives).
- The International Maritime Industries Forum (one representative).
- The Greek Shipping Co-operation Committee (one representative).
- Intercargo (one representative).
- Institute of Quality Assurance (one representative).
- Intertanko (one representative).
- The International Group of P&I Clubs (one representative).

Nominated members of the Committee are elected for a term of service of three years and are eligible for re-election, subject to the membership age limit and unbroken membership of the nominating body they represent during their period of membership.

Six members representing P&I Clubs elected by the Committee for a term of service of one year. P&I Club representatives are eligible for re-election, subject to the membership age limit.

Such persons specially elected by the Committee for a term of service of one year. Specially Elected Members are eligible for re-election, subject to the membership age limit. The number of Specially Elected Members shall be limited not to exceed the balance of the maximum Committee membership of 85 persons. A specially elected member will automatically relinquish his/her membership in this category on being elected as a nominated member of the Committee.

2.2 The Committee is further empowered to elect as Honorary Members of the Committee such persons of distinction and eminence as the Committee shall from time to time think fit.

2.3 With the exception of honorary members, any member of the Committee shall automatically retire from the Committee on reaching the age of seventy years, unless special approval for an additional term of service is recommended by the Committee's Nominations Committee and approved by the Committee each year thereafter.

■ *Section 3*

3.1 The Committee has power to:

- Appoint a Board and delegate thereto such of its powers as it may determine;
- Appoint a General Committee Nominations Committee and determine its powers;
- Appoint a Sub-Committee of Classification and determine its powers and functions;
- Appoint Committees in any country or area to form a liaison between LR and the local maritime, industrial and commercial communities;
- Appoint Technical Committees and determine their functions, powers and duties.

3.2 The Committee has exercised its powers and has appointed such committees and Board.

■ *Section 4*

4.1 National and Area Committees are established in the following:

Countries:

Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany (via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register Asia)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:

Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America ltd)
Nordic countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)

■ *Section 5*

5.1 The main Technical Committee is at present composed of:

		TOTAL
Ex officio:		
•	The Chairman of LR	1
•	The Chairman of the Sub-Committee of Classification	1
Nominated by:		
•	The Committee	18
•	The Royal Institution of Naval Architects	2
•	The Institution of Engineers and Shipbuilders in Scotland	2
•	The Institute of Marine Engineers	2
•	The Institution of Mechanical Engineers	2
•	The Shipbuilders' and Shiprepairers' Association	2
•	The Short Sea Group of the Chamber of Shipping	1
•	The Society of Consulting Marine Engineers and Ship Surveyors	1
•	The Institute of Materials	1
•	The UK Steel Association	1
•	The Honourable Company of Master Mariners	2
•	The Institution of Electrical Engineers	1
•	Federation of British Electrotechnical and Allied Manufacturers' Associations	1
•	The Technical Committee	18
•	The Technical Committee (from other countries)	18
•	The Institute of Refrigeration	1
•	International Oil Companies	2
•	Association of European Shipbuilders and Shiprepairers	1
•	Greek Shipping Co-operation Committee	1
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5.2 All nominations are subject to confirmation by the Committee.

5.3 In addition to the foregoing:
(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.
(b) A maximum of five representatives from National Administrations may, with the consent of the Committee, be co-opted to serve on the Technical Committee. Such representatives may also be elected as members of the Technical Committee under one of the categories identified in 5.1.
(c) Further persons may, with the consent of the Committee, be co-opted to serve on the Technical Committee.

5.4 The function of the Technical Committee is to consider any technical problems connected with LR's business (*see* 1.1(a)) and with the exception of changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies, any proposed alterations in the existing Rules and to frame new Rules for classification as deemed necessary.

5.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may serve one additional term of office with the approval of the Committee.

5.6 In the case of continuous non-attendance of a member, the Committee may withdraw his/her membership.

5.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year.

5.8 Any proposal of the Technical Committee involving any alteration in, or addition to, Rules for classification is referred to the Committee and may be finally approved at the next meeting of the Board if the General Committee so direct.

5.9 The Technical Committee is empowered to:
(a) appoint sub-Committees or panels of the Committee; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organization or industry or private individuals for the purpose of considering any particular problem.

■ *Section 6*

6.1 The Naval Ship Technical Committee (hereinafter referred to as NSTC) is at present composed of not more than 50 members to include nominees of:
- The Royal Navy and the UK Ministry of Defence;
- The Defence Evaluation and Research Agency;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;
- Various maritime bodies and institutions, nominated by the NSTC;
- The Chairman and Chairman of the Sub-Committee of Classification who are *ex officio* members.

6.2 All nominations are subject to confirmation by the Committee.

6.3 All members of the NSTC are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

6.4 The term of office of the NSTC Chairman and of all members of the NSTC is five years. Members may serve one additional term of office with the approval of the Committee. The term of the Chairman may be extended with the approval of the General Committee.

6.5 In the case of continuous non-attendance of a member, the Committee may withdraw that person's membership.

6.6 The function of the NSTC is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

6.7 Meetings of the NSTC shall be convened as necessary but there shall be at least one meeting per year.

6.8 Following approval by the NSTC, details of new Rules (or amendments) will be submitted to the Committee for adoption.

■ *Section 7*

7.1 The Committee has power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Committee, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and ship owner for construction of the ship has been signed, nor within six months of its adoption. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to the Committee.

(c) All reports of survey are to be made by Surveyors authorised by LR to survey and report (hereinafter referred as the Surveyors) according to the form prescribed, and submitted for the consideration of the Committee, or its Sub-Committee of Classification, but the character assigned by the latter is to be subject to confirmation by the Committee or by the Chairman acting on behalf of the Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorized in writing by that owner, to any other person or organization.

(e) Information relating to the status of classification and statutory surveys and suspensions/withdrawls of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(f) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Sub-Committee of Classification that the Sub-Committee of Classification assigns to it.

■ *Section 8*

8.1 No Lloyd's Register Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 9*

9.1 The Committee has power to:

(a) determine the amounts to be charged for the services provided by LR or for any of its publications;

(b) withhold or, if already granted, to suspend or withdraw any class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee.

■ *Section 10*

10.1 In this section:

(i) 'Services' means the services provided by LR; and

(ii) 'Contract' means the contract for supply of the Services; and

(iii) the 'LR Group' includes LR, its affiliates and subsidiaries, and the officers, directors, employees, representatives and agents of any of them, individually or collectively.

10.2 LR's services do not assess compliance with any standard other than the applicable LR Rules, international conventions, and other standards agreed in writing by LR and the Client.

10.3 In providing Services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, the LR Group will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's Services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then LR will pay compensation to the Client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

10.4 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of user or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

10.5 LR’s omission or failure to carry out or observe any stipulation, condition, or obligation to be performed under the Contract will not give rise to any claim against LR or be deemed to be a breach of contract if the failure or omission arises from causes beyond LR’s reasonable control.

10.6 Any dispute about the Services or the Contract is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ *Introduction*

Definition of Hull Naval Class

Naval ship Classification may be regarded as the development and worldwide implementation of published Rules and Regulations, which, in conjunction with proper care and conduct on the part of the Owner, will provide for:

1. the structural strength and the watertight integrity of all essential parts of the hull and its appendages; this includes compliance with a suitable damage stability standard accepted by LR;
2. the operation and functioning of associated systems installed for operational requirements relating to the ship type; and
3. the effectiveness of other defined features and systems which have been built into the ship in order to establish and maintain basic conditions on board whereby appropriate stores, fuels, equipment and personnel can be safely carried whilst the ship is at sea, at anchor, or moored in harbour.

A naval ship is said to be in Class when the Rules and Regulations which pertain to it have been complied with, or, compliance, equivalent to the Rules, has been ascertained.

LR maintains these provisions by way of periodical visits by its Surveyors to the ship as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Records of any defects found, or modifications carried out, between visits by LR surveyors, which may affect Classification, are to be maintained. Any defects found are to be reported to LR with the minimum of delay.The records will form the basis of remedial action, where necessary for maintenance of Class.

Military Distinctions

Military Distinction notations are awarded by LR as shown in Part 4 of these Rules. LR requires demonstration of the capability of the ship to withstand specified hostile military action without loss of capability. It is the responsibility of the navy or designer to specify and quantify the weapon performance and scenarios to be studied. A Military Distinction notation is awarded by LR on the basis that the assessment presented has been conducted in accordance with agreed procedures and the ship constructed in a manner that reflects the design requirements.

LR is to be informed of any incident of the ship sustaining damage. Such ships are to be made available for survey thereafter at the earliest possible opportunity.

Options

The handling of safety matters such as ship's stability, life saving appliances, pollution prevention arrangements and structural fire protection, fire detection and extinction arrangements is the prerogative of the Owner and his delegated Naval Authority. However, where these matters are delegated to LR they will be undertaken in accordance with agreed procedures and appropriate class notations will be assigned and entered into the *Register Book*.

Machinery Naval Class

Where agreed Naval Ship Classification will provide for the safety and reliability of propulsion, steering and other essential auxiliary engineering systems, including the arrangements for lifting appliances. When Machinery Naval Class is adopted, the aspects included in the Definition of Hull Naval Class also apply.

Transfer of Information

To achieve naval class it is imperative to ensure that communication between LR, the Owner, Navy, Prime Contractor, Designer and Builder is effective. In designing, building and maintaining a ship to class it is essential that liaison between the various parties involved is assured. In particular, formal written contracts are essential for commercial reasons between the contractors, but an additional responsibility rests with all participants to ensure that naval class leads to a transparency of information during construction and thereafter.

■ *Section 1*
Conditions for Classification

1.1 Framework of Classification

1.1.1 The Rules and Regulations for the Classification of Naval ships, hereinafter referred to as the Rules, are applicable to those types of ship which are defined in 2.1.

1.1.2 The Rules do not, unless stated or implied in the Class notation, provide for special distributions or concentrations of loading associated with the operation of the ship. LR may require additional strengthening to be fitted in any ship which may be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration.

1.1.3 Compliance with the Rules does not relieve the designer of his responsibilities for compliance with the specification and the requirements for the overall design and in-service performance of the ship.

1.1.4 New ships built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a Class and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules.

1.1.5 In addition to confirming compliance with the Rules, LR will, in conjunction with the Naval Authority, require to be satisfied that the ship is suitable for the geographical or other limits or conditions of the service requested.

1.1.6 Preparations required to permit a ship with a service area restriction specifying some service limitation to undertake duties that take the ship beyond the specified service restriction, either from port of building to its service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which affect the conditions for which a Class has been assigned, must be reported to LR. (Note that some ships have a grounding condition included for Class).

1.1.8 Where LR is acting on behalf of the Naval Authority, any relevant requirements of the Naval Authority are to be identified and advised to LR in writing.

1.1.9 It is a requirement of classification that a suitable sub-division and stability standard, specified by the Naval Authority, is adopted and complied with. LR will provide advice on this aspect at the request of the Owner/Naval Authority. Where the Naval Authority, or its designated agency, approves the arrangements for compliance with the required stability and subdivision standards a copy of the following documentation is to be submitted:

- approval documentation issued by the Naval Authority stating that arrangements have been examined against the required standard and are acceptable.
- accepted arrangements of openings, closing appliances, vents, etc., such that the limits of the watertight integrity may be defined at the design draught. From these limits the pressure heads for watertight structure and watertight/weathertight closing requirements for openings, etc., can be identified.

Alternatively, Lloyd's Register (hereinafter referred to as 'LR') will approve the arrangements against the required standards.

1.1.10 It is a requirement of classification that fire safety arrangements are to comply with and be maintained in compliance with specified standard(s). The specified standard(s) and on-going certification regime are to be notified to LR by the Naval Authority in writing. LR will provide advice on this aspect at the request of the Owner/Naval Authority, *see also* the **FIRE** notation, Ch 2,3.9.

1.1.11 It is a requirement of classification that lifting appliance arrangements are to comply with and be maintained in compliance with specified standard(s). The specified standard(s) and on-going certification regime are to be notified to LR by the Naval Authority in writing. LR will provide advice on this aspect at the request of the Owner/Naval Authority, *see also* the **LA** notation, Ch 2,3.9.

1.1.12 It is a requirement of classification that magazine safety arrangements are to comply with and be maintained in compliance with specified standard(s). The specified standard(s) and on-going certification regime are to be notified to LR by the Naval Authority in writing. LR will provide advice on this aspect at the request of the Owner/Naval Authority.

1.1.13 Where an on board computer system having longitudinal strength capability, which is required by the Rules, is provided on a new ship, or newly installed on an existing ship, then the system is to be certified in respect of longitudinal strength in accordance with the document entitled *Approval of Longitudinal Strength and Stability Calculation Programs*, *see also* Pt 5, Ch 4,6.

1.2 Application

1.2.1 Except in the case of a special directive by LR no new Regulation or alteration to any existing Regulation relating to the character of Classification or to Class notations is to be applied to existing ships.

1.2.2 Except in the case of a special directive by LR no new Rule or alteration in any existing Rule materially affecting Classification is to be applied compulsorily within six months of its adoption, nor after the approval of the original midship section or equivalent structural plans. Where it is desired to use existing previously approved plans for a new contract, written application is to be made to LR.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Owner's responsibilities

1.4.1 The Owner is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Owner should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.4.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey. LR's Surveyors may not be in continual attendance. As construction, outfitting and refitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors, have been complied with.

1.4.3 Where the Navy/Owner identifies standards, conducts audits or issues certificates, and the responsibility has not been delegated to LR, LR is to be advised of the identity of the Naval Authority and is to be furnished with all appropriate standards and to have full access to the Naval Authority at all times.

1.5 Documentation

1.5.1 It is acknowledged that the Owner may wish to retain the originals of Certificates issued by LR, however, naval ships are required to carry the following documentation on board so that the attending surveyor is able to carry out his duties (certified copies of Certificates are acceptable):

(a) Endorsable Certificate of Class.
(b) C11(N) – Record of watertight and weathertight closing arrangements.
(c) Approved Stability information and damage control plan and the following as applicable.
(d) Lifting Appliances Certificate.
(e) Pollution record of equipment.
(f) Tonnage Certificate.
(g) Safety Equipment record of equipment.
(h) Fire control plan.

1.6 Pre-Contract and Through-Life advice

1.6.1 LR will provide advice on the potential conditions of Classification for a naval ship, so that the Owner may specify design, construction and operation parameters that satisfy the requirements for Classification whilst being consistent with the intended application. A number of optional matters can be incorporated into the Conditions for Classification of the ship (*see* Ch 2,3.9.10 to 3.9.13 and Ch 3,2.4). LR will also advise on Alterations and Additions and other matters which may affect the Conditions for Classification, and to liaise with the Owner on any other matter of concern for the purpose of assisting the Owner in establishing the parameters applicable to the ship's operational needs.

■ *Section 2* Scope of the Rules

2.1 Applicable ship types

2.1.1 The Rules are applicable to naval ships designed and constructed for the purpose of carrying and operating naval systems. For the purposes of Classification, naval ships can be grouped into three categories as follows:

(a) **NS1 ships**
This category covers ships used for the deployment of aircraft or equipment and ships which may be used as centres of command. Designed for world wide operation and usually supported by ships from the NS2 category.
Typically it will cover ships above 140 m in length with a deep displacement of 10000 tonnes or more. It will include aircraft carriers, helicopter and amphibious support ships, and assault ships.

(b) **NS2 ships**
This category covers ships used to defend NS1 ships as part of a task force or act as independent units. They may have a variety of sole or multiple roles including air defence, anti submarine, sea defence, shore support and will be designed for world wide operation.
Typically it will cover ships of length 70 m to 140 m with displacements of 1300 tonnes to 20000 tonnes. NS2 ships may be described as cruisers, frigates, destroyers, corvettes or similar.

(c) **NS3 ships**
This category covers ships that have a front line role but are not covered by the above descriptions. This category includes a variety of ships typically below 1500 tonnes displacement. They may operate independently or as part of a task force and are usually designed and constructed for specific roles such as mine sweeping, beach landings, coastal defence or fast patrol duties. A restricted service area may be specified.

There are special requirements for hovercraft, mine-sweepers, landing ships, which are to be designed in accordance with the appropriate sections of relevant LR Rules and Regulations.

2.2 Definitions

For the purpose of the Rules and Class notations, the definitions given in 2.2.1 to 2.2.13 will apply.

2.2.1 **Clear water**. Water having sufficient depth to permit the normal development of wind generated waves.

2.2.2 **Designer**. The organisation which provides the design and constructional plans.

2.2.3 **Fetch**. The extent of clear water across which a wind has blown before reaching the ship.

2.2.4 **Maximum speed**. Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the ship is certified in smooth water.

2.2.5 **Mono-hull ship**. A mono-hull ship is a ship whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.6 **Naval Authority**. An authority or authorities nominated by the Owner responsible for providing regulation associated with procurement and support of the ship. The Naval Authority may also be responsible for identifying appropriate standards, auditing and certification. The Naval Authority could be a Government department, Statutory Authority, LR or an independent organisation with appropriate standing.

2.2.7 **Navy**. The operator of the ship. The Navy may also be the Owner.

2.2.8 **Owner**. Generally, this will be the government department responsible for naval procurement and support. In certain circumstances, the Navy may operate ships chartered from other Owners, in which case the Owner as defined in these regulations is to be agreed with LR on a case by case basis.

2.2.9 **Client**. LR's point of contact with the organisation contracting it to undertake work.

2.2.10 **Operational envelope**. The operational envelope defines the ship's service in terms of operational speeds, wave heights, displacements, service area, temperatures, motions, flight deck operations and radar, and is to be provided by the Owner.

2.2.11 **Reasonable weather**. Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.
(b) Motions such as do not impair the efficient operation of the ship.

2.2.12 **Sheltered water**. Water where the fetch is six nautical miles or less.

2.2.13 **Stability information**. Documents required for stability certification. The form of information is to be specified by the Naval Authority.

■ *Section 3*
Character of Classification and Class notations

3.1 General

3.1.1 This section details the character symbols, Class notations which comprise the Class assigned to naval ships.

3.1.2 The character symbols identify whether the ship is built under LR Class and survey, the suitability for sea-going service, the provision of anchor handling equipment and the rules used for the construction of the ship. The character symbols are described in 3.2.

3.1.3 The Class notations detail the particular features of the ship which are required to be especially considered in order to verify where additional care has been taken in particular aspects of the design of the ship. These Class notations are subject to an approval process in order to satisfy Classification requirements.

3.1.4 Optional notations detail particular features of the ship which may not form part of the hull approval process required for Classification. Typically they include details of military design features, machinery and safety/environmental aspects of the vessel.

3.1.5 The following are examples of character symbols, and Class notations as they would appear in the *Register Book*:

✠ **100A1 NS2 Frigate**,
✠ **LMC, SCM, SA1, SDA, ESA1, RSA2, Ice Class 1C**,
✠ **MD, SEA, EER.**

3.2 Character symbols

3.2.1 All ships, when Classed, will be assigned a character of Classification comprising one or more character symbols as applicable, e.g. ✠ **100A1**.

3.2.2 A full list of character symbols for which a ship may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of Classing, to new ships constructed under Special Survey, in compliance with the Rules, and to the satisfaction of LR.

100 This character figure will be assigned to all ships considered suitable for sea-going service for Hull Naval Class.

A This character letter will be assigned to all ships which have been built or accepted into Class in accordance with the Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:
(a) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.
(b) Ships Classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

E This character letter will be assigned to ships on which LR has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

3.2.3 For Classification purposes either the character figure **1** or the character letter **E** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the Class of the ship will be liable to be withheld.

3.3 Class notations

3.3.1 When considered necessary by LR, or when requested by an Owner and agreed by LR, a Class notation will be appended to the character of Classification assigned to the ship. The Class notation may consist of any of the following:

(a) a ship type notation, *see* 3.4;
(b) a service area notation, *see* 3.5;
(c) a hull girder strength notation, *see* 3.6;
(d) military distinction notations, *see* 3.7;
(e) machinery and engineering systems notations, *see* 3.8;
(f) other notations, *see* 3.9.

3.4 Ship type notations

3.4.1 The ship type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the ship has been designed and constructed.

3.4.2 A list of ship type notations for which a ship may be eligible is:

NS1 This notation will be assigned to NS1 category naval ships, as defined in Section 2.1.1(a).

NS2 This notation will be assigned to NS2 category naval ships, as defined in Section 2.1.1(b).

NS3 This notation will be assigned to NS3 category naval ships, as defined in Section 2.1.1(c).

3.4.3 The ship type notation will be followed by a description which indicates the operational role for which the ship is designed and the hull form type, if of unusual form. The following are examples of the description of the ship's role:

Destroyer
Cruiser
Helicopter Carrier
Aircraft Carrier
Frigate
Corvette
Amphibious Assault Ship
Amphibious Transport Dock
Landing Craft
Minehunter
Minelayer
Mine-sweeper
Patrol ship
Fast Attack Craft
Fast Strike Craft
Fast Patrol Craft
Offshore Patrol Vessel
Survey ship.

3.5 Service area notations

3.5.1 All ships Classed under the Rules will be assigned a service area notation **SA** followed by a number or letter, e.g. **SA1**.

3.5.2 Service area notations listed below are available. The definitive extents of the service areas are shown in Vol 1, Pt 5, Ch 2, Fig. 2.2.2 and Vol 1, Pt 5, Ch 2, Table 2.2.3.

SA1 **Service Area 1** covers ships having unrestricted world wide operation. Service Area 1 includes operation in all other service areas

SA2 **Service Area 2** is primarily intended to cover ships designed to operate in tropical and temperate regions. This service area excludes operating in sea areas for which a **SA1** notation is required.

SA3 **Service Area 3** is primarily intended to cover ships designed to operate in tropical regions. This service area excludes operating in sea areas for which a **SA1** or **SA2** notation is required.

SA4 **Service Area 4** covers ships designed to operate in Sheltered water, as defined in Pt 1, Ch 2,2.2.12. This service area excludes operating in sea areas for which a **SA1**, **SA2** or **SA3** notation is required.

SAR **Service Area Restricted** covers ships that are designed to operate in a predetermined and contiguous area of operation.

3.5.3 More details of the service areas and extents are given in Pt 5, Ch 2.

3.6 Hull strength notations

3.6.1 The following notations are available for naval ships with regard to global hull girder strength aspects:

ESA1 **Extreme Strength Assessment**. This notation will be assigned if it has been demonstrated that the extreme hull girder strength meets the requirements of a specified performance level with calculations performed using a simple elastic type analysis.

ESA2 **Extreme Strength Assessment**. This notation will be assigned if it has been demonstrated that the extreme hull girder strength meets the requirements of a specified performance level with calculations performed using an elasto-plastic type analysis.

RSA1 **Residual Strength Assessment**. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using a simple elastic type analysis.

RSA2 **Residual Strength Assessment**. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using an elasto-plastic type analysis.

RSA3 **Residual Strength Assessment**. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using a 3D non-linear finite element analysis.

TLA **Total Load Assessment**. This notation will be assigned if the scantlings have been verified using a total load approach.

SDA **Structural Design Assessment**. This notation will be assigned when direct calculations in accordance with agreed procedures have been applied.

FDA **Fatigue Design Assessment**. This notation will be assigned when an appraisal has been made of the fatigue performance of the structure in accordance with agreed procedures.

3.7 Military Distinction notations

3.7.1 Military Distinction notations may be assigned if a particular feature relating to military loads has been incorporated in the design. The requirements for all the Military distinction notations are given in Part 4.

✠ MD This military distinction notation will be assigned when military aspects of the ship have been constructed under LR's Special Survey and in accordance with LR's Rules and Regulations.
In particular, the following confidential notations are available, and details will be known only to the Owner and LR.

MD This military distinction notation will be assigned when military aspects of the ship have been assessed in accordance with LR's Rules and Regulations. In particular, the following confidential notations are available, and will be known only to the Owner and LR.

EB1 **External air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the rule loads and structural design methodology.

EB2 **External air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the rule loads and an elasto-plastic structural design methodology.

EB3 **External air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the rule loads and an finite element structural design methodology.

EB4 **External air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using a full 3D non-linear code for the loads and/or structural design.

IB1 **Internal air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to prevent the spread of an internal blast compatible with a specified performance level in accordance with rules requirements.

IB2 **Internal air blast notation**. This confidential notation indicates that the ship is capable of meeting the structural requirements to prevent the spread of an internal blast compatible with a specified performance level in accordance with rules requirements, supplemented by additional testing or analysis work.

FP1 **Fragmentation protection notation**. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand a defined fragmentation threat compatible with a specified performance level using the rule structural requirements.

FP2 **Fragmentation protection notation**. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand a defined fragmentation threat compatible with a specified performance level using fragmentation penetration algorithms.

SP **Small arms protection**. This confidential notation indicates that the ship is capable of meeting the local strengthening requirements to withstand an attack from a defined small arms threat compatible with a specified performance level.

SH1 **Shock enhancement notation**. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand an underwater shock compatible with a specified performance level. The strength calculations are performed using a simplified approach.

SH2 **Shock enhancement notation**. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand an underwater shock compatible with a specified performance level. The strength calculations are performed using a finite element modal in which the shock pulse is modelled using a suitable boundary element.

SH3 **Shock enhancement notation**. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand an underwater shock compatible with a specified performance level. The strength calculations are performed using a hydrocode in which the shock pulse is modelled by attaching a volume of fluid to the structural model.

WH1 **Whipping assessment notation**. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using a simple elastic type analysis.

WH2 **Whipping assessment notation**. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using an elasto-plastic type analysis.

WH3 **Whipping assessment notation**. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using a 3D non-linear finite element analysis.

Table 2.3.1 Hull, Military and Other Class Notations

Mandatory Notations		Other Notations		
Ship Type	Service Area	Hull Strength	Military Distinction ✠ MD	Others
See 3.4 (Select one:) **NS1** **NS2** **NS3** Description of ship's role Examples: Cruiser Helicopter Carrier Aircraft Carrier Destroyer Frigate Corvette Amphibious Assault Ship Amphibious Transport Dock Landing Craft Minehunter Minelayer Mine-sweeper Patrol Ship Survey Ship e.g. NS1 Helicopter Carrier Military Operations **AIR** Aircraft Operations	*See* 3.5 (Select one:) **SA1** Service Area 1 **SA2** Service Area 2 **SA3** Service Area 3 **SA4** Service Area 4 **SAR** Service Area Restricted	*See* 3.6 **ESA1 ESA2** Extreme Strength Assessment **RSA1 RSA2 RSA3** Residual Strength Assessment **TLA** Total Load Assessment **SDA** Structural Design Assessment **FDA** Fatigue Design Assessment	*See* 3.7 **IB1 IB2** Internal Air Blast **EB1 EB2 EB3 EB4** External Air Blast **SH1 SH2 SH3** Shock Enhancement **WH1 WH2 WH3** Whipping Assessment **FP1 FP2** Fragmentation Protection **SP** Small Arms Protection	*See* 3.9 **LA LA(N)** Lifting Appliances **SD** Special Duties **CM** Construction Monitoring **SEA (HSS-n)** Ship Event Analysis Hull Surveillance System **SEA (VDR)** Ship Event Analysis Voyage Data Recorder **SEA (VDR-n)** Sea Event Analysis Voyage Data Recorder (strain gauges) **ES** Enhanced Scantlings **SERS** Ship Emergency Response Service **EER** Escape, Emergency Access, Evacuation and Rescue (*see* Note) **FIRE** Fire Protection (*see* Note) **LSAE** Life Saving and Evacuation (*see* Note) **ESC** Escape and Emergency Access (*see* Note) **SNC** Safety of Navigation and Communication (*see* Note) **POL** Pollution Prevention **Ice Class** Navigation in Ice **LMA** Manoeuvring Assessment **CEPAC** Crew and Embarked Personnel Comfort **EP** Environmental Protection **LI** Approved Loading Instrument **HPMS** Hull Planned Maintenance Scheme

NOTE
Star Endorsement (*) may be assigned to this notation where the arrangements on board are in accordance with stated National Administration requirements.

Table 2.3.2 Machinery Class Notations

Machinery Notations
See 3.8

✠ LMC
Propulsion and essential machinery

✠̄ LMC
Propulsion and essential machinery

LMC
Propulsion and essential machinery

SCM
Screwshaft Condition Monitoring

TCM
Turbine Condition Monitoring

PMR
Propulsion System Redundancy

PMR*
Propulsion System Redundancy in Separate Compartments

SMR
Steering System Redundancy

SMR*
Steering System Redundancy in Separate Compartments

PSMR
Propulsion and Steering System Redundancy

PSMR*
Propulsion and Steering System Redundancy in Separate Compartments

ELS
Electrical power supplies to STANAG 1008

AG1
Enhanced analysis of propulsion and/or auxiliary gear elements

AG2
Enhanced three dimensional finite element analysis of propulsion and/or auxiliary gear elements

AP1
Enhanced assessment of propeller manufacturing tolerances on fast ships and craft

AP2
Enhanced assessment of propeller manufacturing tolerances having reduced noise characteristics

MPMS
Machinery Planned Maintenance Scheme

MCM
Machinery Planned Maintenance Scheme with Condition Monitoring

RCM
Machinery Planned Maintenance Scheme with Reliability Centred Maintenance

RAS(ABV)
Replenishment at Sea, Astern, Abeam and VERTREP

RAS(AB)
Replenishment at Sea, Abeam and Astern

RAS(AV)
Replenishment at Sea, Astern and VERTREP

RAS(BV)
Replenishment at Sea, Abeam and VERTREP

RAS(A)
Replenishment at Sea, Astern

RAS(B)
Replenishment at Sea, Abeam

RAS(V)
Replenishment at Sea, VERTREP

(NT)
Additional to **RAS( )**, NATO requirements

UMS
Unattended Machinery Spaces

CCS
Centralised Control Station

ICC
Integrated Computer Control

IP
Integrated Propulsion

DP(CM)
Dynamic Positioning
(Centralised Remote Manual Controls)

DP(AM)
Dynamic Positioning
(Automatic main and manual standby controls)

DP(AA)
Dynamic Positioning
(Automatic main and automatic standby controls)

DP(AAA)
Dynamic Positioning
(Automatic main and automatic standby controls with additional /emergency automatic control)

NAV
Navigation equipment

NAV1
Navigation equipment

IBS
Integrated Bridge System

3.8 Machinery and Engineering Systems notations

3.8.1 The following class notations are associated with the machinery construction and arrangement, and may be assigned:

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under Special Survey and in accordance with LR's Rules and Regulations.

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition the whole of the machinery will be required to have been installed and tested under Special Survey in accordance with LR's Rules and Regulations.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under Special Survey, but the existing machinery its installation and arrangement has been tested and found acceptable.

SCM **Screwshaft Condition Monitoring**. This notation may be assigned when oil lubricated screwshaft arrangements with approved oil glands are fitted and the requirements of Ch 3,13.3 are complied with.

TCM **Turbine Condition Monitoring**. This notation will be assigned when the main propulsion steam turbines are provided with approved vibration monitoring equipment and the requirements of Ch 3,8.2 are complied with.

PMR This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PMR* This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and where the machinery is installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

SMR This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system for any steering system. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

SMR* This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system to any steering system and where the steering systems are installed in separate compartments such that, in the event of the loss of one compartment, steering capability will continue to be available. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PSMR This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PSMR* This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. The propulsion and steering arrangements are to be installed in separate compartments such that in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

ELS This notation will be assigned where both the quality and integrity of on board electrical power supplies meet the requirements of NATO Standardization Agreement (STANAG) 1008. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

AG1 This notation will be assigned where the design of gearing for propulsion and/or auxiliary purposes has used enhanced analysis methods to provide detailed knowledge of the reliability of the gear elements and where noise excitation is required to be minimised for anticipated service conditions.

AG2 This notation will be assigned where the design of gearing for propulsion and/or auxiliary purposes has in addition to the requirements for AG1, used three dimensional finite element analysis for determining the flexibility of the geometry of the mating gears.

AP1 This notation will be assigned to fast ships and craft where the propellers require an enhanced assessment of the manufacturing tolerances to control cavitation and noise characteristics.

AP2 This notation will be assigned where ships have propellers that are required to have reduced noise characteristics and have had an enhanced assessment of the manufacturing tolerances.

MPMS This notation will be assigned where the machinery installation has an approved planned maintenance scheme that incorporates preventive maintenance procedures and the requirements of Ch 3,15 are complied with.

MCM This notation will be assigned where an approved planned maintenance scheme for machinery incorporates condition monitoring techniques that are acceptable to LR and the requirements of Ch 3,15 are complied with.

RCM This notation will be assigned where an approved planned maintenance scheme for machinery incorporates a reliability centred maintenance analysis that is acceptable to LR and the requirements of Ch 3,15 are complied with.

RAS(ABV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern, abeam and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(AB) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam and astern only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(AV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(BV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(A) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(V) This notation will be assigned where a vessel has replenishment at sea systems that enable operations VERTREP only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(B) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam only. It also denotes that the arrangements are in accordance with LR Rules.

(NT) This notation will be assigned in addition to a **RAS( )** notation where a vessel complies with NATO replenishment at sea requirements.

3.8.2 The following class notations are associated with the machinery control and automation, and may be assigned

UMS This notation may be assigned when the arrangements are such that the ship can be operated with the Machinery Spaces Unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a Centralised Control Station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of the ship operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IP This notation may be assigned to a ship classed with LR when the arrangements of the machinery are such that the propulsion equipment and all the essential auxiliary machinery is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment have been arranged, installed and tested in accordance with LR's Rules.

3.8.3 The following class notations are associated with dynamic positioning arrangements, and may be assigned.

DP(CM) This notation may be assigned when a ship is fitted with centralised remote manual controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AM) This notation may be assigned when a ship is fitted with automatic main and manual standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AA) This notation may be assigned when a ship is fitted with automatic main and automatic standby controls for position keeping and with position reference system(s) and environmental sensor(s). It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

DP(AAA) This notation may be assigned when a ship is fitted with automatic main and automatic standby controls for position keeping together with an additional/emergency automatic control unit located in a separate compartment and with position reference systems and environmental sensors. It denotes that the machinery and control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

PCR The class notation will be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a ship is capable of holding heading and position under a standard set of environmental conditions (North Sea).

3.8.4 The following class notations are associated with navigation safety, and may be assigned:

NAV This notation will be assigned when a superior bridge layout and level of navigation equipment are provided. It denotes that the navigational installation has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

NAV1 This notation will be assigned when a superior bridge layout and level of equipment are such that the ship is considered suitable for safe periodic operation under the supervision of a single watchkeeper on the bridge. It denotes that the navigational installation has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

IBS This notation will be assigned where an integrated bridge system is fitted to provide electronic chart display, track planning and automatic track following, centralised navigation information display, and bridge alarm management. It denotes that the integrated bridge system has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.8.5 Machinery and Engineering Systems class notations will not be assigned to ships where the hulls are not classed or intended to be classed with LR.

3.8.6 Other class notations may be assigned where the machinery and engineering systems are in accordance with the requirements of the additional features included in Volume 3 of the Rules and Regulations.

3.9 Other notations

3.9.1 **Mandatory operational notation**.

AIR Mandatory notation for ships that operate aircraft in accordance with the requirements of Pt 4, Ch 2,10 for the landing, manoeuvring and parking areas.

3.9.2 **LA**. This special feature Class notation will be assigned to the ship in respect of the lifting appliances fitted which are designed and built in accordance with LR's *Code for Lifting Appliances in a Marine Environment* (LAME) or equivalent standard. This notation will be assigned in association with a register of lifting appliances listing the appliances covered. The register, which is to be attached to the Classification Certificate, is the responsibility of the designer/Owner and should include the following lifting appliances, where fitted as appropriate:

(a) Bow, side and stern doors serving as ramps and/or serve to provide watertight integrity of the ship.
(b) Vehicle ramps.
(c) Moveable decks.
(d) Aircraft lifts, stores lifts and munitions lifts.
(e) Cranes.
(f) Davits.
(g) Replenishment at sea positions.
(h) Engineers lifting positions.
(j) Eye plates and securing devices.
(k) Lifting points on vessels which are launched and recovered by a lifting appliance, *see* Pt 3, Ch 5,11.4.
(l) Miscellaneous lifting positions.
(m) Towed body attachments.

The notation will be retained so long as the appliances are found upon examination by LR at the prescribed surveys to be maintained in accordance with the standard.

3.9.3 **LA(N)**. Where additional requirements of the Naval Authority have been complied with, the ship will be entitled to the notation **LA(N)**. These requirements are to be clearly defined and referenced in the register of lifting appliances.

3.9.4 **LI Loading Instrument**. This notation will be assigned where an approved loading instrument has been installed either as a Class or Owner's requirement.

3.9.5 **CM Construction Monitoring**, complements the **SDA** and **FDA** notations and will be assigned when the controls in construction tolerances have been applied and verified.

3.9.6 **SEA(HSS-n), SEA(VDR), SEA(VDR-n) Ship Event Analysis**. At the Owner's request, and in order to enhance safety and awareness onboard during ship operation, provisions can be made for a hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship's personnel that these levels or the frequency and magniude of slamming motions are approaching a level where corrective action is advisable. The extension -n signifies the number of fitted strain gauges if connected to the system. The following option extensions will be added to the notation:

L The display and recording of the relevant strength information.

M The display and recording of the ship's motion.

N The facility to display and record navigational information.

VDR An interface with the ships voyage data recorder system to enable the recording of hull stress, ship motion and hull pressure information.

3.9.7 **ES Enhanced Scantlings.** Available where scantlings in excess of the approved Rule minimum requirements are fitted at defined locations. For example, the note ES+1 will indicate that an extra 1 mm has been fitted to the hull envelope plating (i.e. deck, side and bottom).

3.9.8 **SERS Ship Emergency Response Service**. This service, offered by LR provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship. Where an Owner adopts this service, the notation **SERS**, 'Ship is registered with LR's Ship Emergency Response Service' is available.

3.9.9 **EER Escape, Emergency Access, Evacuation and Rescue**. This notation will be assigned to naval ships which demonstrate compliance with all the requirements for **FIRE**, **ESC** and **LSAE** notations. It also denotes that the systems and their arrangements have been integrated in such a manner so as to support safe and effective task performance.

3.9.10 **FIRE Fire Protection**. This notation will be assigned to naval ships which are shown to have levels of fire protection that incorporate the functional requirements and objectives of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.9.11 **ESC Escape and Emergency Access**. This notation will be assigned to naval ships which demonstrate levels of personnel safety in the event of a 'prepare to evacuate' situation and emergency access arrangements that incorporate the functional requirements and objectives of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.9.12 **LSAE Life-saving and Evacuation Arrangements**. This notation will be assigned to naval ships which demonstrate the provision of life-saving and rescue equipment on board that incorporates the functional requirements and objectives of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.9.13 **SNC Safety of Navigation and Communication**. This notation will be assigned to naval ships which demonstrate levels of safety of navigation and communication arrangements on board that incorporate the functional requirements and objective of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.9.14 **POL Pollution Prevention**. This notation will be assigned to naval ships which demonstrate that the pollution prevention arrangements on board that incorporate the functional requirements and objectives of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.9.15 **Ice Class notation**. An appropriate class notation for navigation in ice may be assigned when the hull structural and machinery installation are such that the ship may be operated in defined ice conditions, *see* below. The notation denotes that the hull structural arrangements and machinery installation have been designed, constructed, installed and tested in accordance with LR Rules or its equivalent thereto. The Class notations available are described below:

(a) **Ice Class 1AS.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 1,0 m.
(b) **Ice Class 1A.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,8 m.
(c) **Ice Class 1B.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,6 m.
(d) **Ice Class 1C.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,4 m.

If operation in first year is defined by the operational requirement as an emergency feature then special consideration will be given to the use of fully plastic design criteria for the shell plating. In such cases the ice class notation will be annotated with *.

3.9.16 **LMA.** This notation will be assigned where the ship's manoeuvring capability has been assessed in conjunction with engine and propulsion performance. It denotes that the manoeuvring performance has been verified through trials in accordance with LR's Rules.

3.9.17 **CEPAC.** This notation will be assigned where the noise and vibration levels in crew and embarked personnel spaces have been assessed and meet acceptance criteria for comfort. It denotes that the noise and vibration levels have been measured and reported in accordance with LR's Rules. Numerals **1** or **2** following the **CEPAC** notation indicate the acceptance criteria to which the noise and vibration levels have been assessed.

3.9.18 **EP.** This notation will be assigned where the environmental protection arrangements for prevention of pollution of the sea and of the air demonstrate compliance with the relevant annexes of MARPOL. It denotes that the assessment for compliance with MARPOL has been carried out in accordance with LR's Rules. Supplementary characters **A** Anti-fouling coatings, **B** Ballast water management, **F** Protected fuel tanks, **G** Grey water, **N** Oxides of nitrogen in exhaust emissions, **R** Refrigeration systems and **S** Oxides of sulphur in exhaust emissions reflect compliance with additional requirements.

3.9.19 **HPMS.** This notation will be assigned where the hull structure has an approved planned maintenance scheme that incorporates maintenance and inspections by authorised ship's staff and the requirements of Ch 3,14 are complied with.

3.9.20 **SD Special Duties Notation**. A special duties notation will be recorded in the *Register Book* indicating that the ship has been designed, modified or arranged for special duties other than those implied by the type notation. Ships with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

3.9.21 **PCWBT Protective Coating in Water Ballast Tanks**. This notation will be assigned to indicate that the ship's water ballast tanks are coated and that the coating remains efficient and well maintained.

■ *Section 4* Surveys – General

4.1 New construction

Plan Appraisal

4.1.1 When it is intended to build a ship for Classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of LR before the work is commenced. Critical Areas (*see* Ch 3,1.5.3) will be identified at this stage. Any additional plans submitted will not be subject to appraisal or approval without separate agreement. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval, under separate arrangements.

4.1.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

4.1.3 The materials used in the construction of hulls and machinery intended for Classification are to be of good quality and free from defects and are to comply with the requirements of the Rules. Material is to be manufactured by works approved by LR. Alternatively, tests to the satisfaction of LR will be required to demonstrate the suitability of the material.

4.1.4 Copies of the latest approved plans, essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and are thereafter required to be kept on board.

4.1.5 If requested LR will check intact and damage stability calculations and approve the Stability information in accordance with a standard acceptable to the Naval Authority and LR.

4.1.6 **Fire Protection – FIRE.** The arrangements for fire protection, detection and extinction are to be examined to ensure that the following fire protection objectives have been satisfied:

(a) **Fire Prevention Objective**. The ship is to be designed and equipped so as to reduce the risk of the occurrence of fire or explosion, taking due account of its operational role.
(b) **Fire Detection Objective**. The ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion.
(c) **Fire Extinguishing Objective**. The ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished.
(d) **Containment Objective**. The ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin.
(e) **Personnel Hazard Objective**. All reasonable measures are to be taken to prevent hazards to personnel as a result of fire.
(f) **System Interaction Objective**. The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable.
(g) **Command and Control Objective**. Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated.
(h) **Structural Integrity Objective**. Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat.

4.1.7 **Pollution Prevention – POL (Optional)**
The arrangements for prevention of pollution of the sea and air from the ship are to be examined to ensure that the following MARPOL Regulations have been complied with:
(a) MARPOL Annex I (Prevention of Pollution by Oil)
(b) MARPOL Annex V (Prevention of Pollution by Garbage)
(c) MARPOL Annex IV (Prevention of Pollution by Sewage)
(d) MARPOL Annex VI (Prevention of Air Pollution)

4.1.8 **Life-Saving and Evacuation – LSAE**
The arrangements for life-saving and evacuation are to be examined to ensure that the following life-saving and evacuation objectives have been satisfied:
(a) **Evacuation Objective**. Arrangements are to be provided to enable personnel to evacuate the ship safely and in a time acceptable to the Naval Authority.
(b) **Personnel Protection Objective**. Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft.
(c) **Rescue Objective**. The ship is to be suitably equipped to rescue personnel from the water.
(d) **Command and Control Objective**. The ship is to be equipped and manned so that command of all evacuation and life-saving situations can be maintained.

4.1.9 **Escape and Emergency Access – ESC.**
The arrangements for escape and emergency access are to be examined to ensure the following escape of personnel and emergency access objectives have been satisfied:
(a) **Escape of Personnel Objective**. The ship is to be arranged so that all spaces have means of safe and effective escape for personnel to a designated place of safety, during reasonably foreseeable emergency situations.
(b) **Emergency Access Objective**. The ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises.

4.1.10 **Safety of Navigation and Communications – SNC.** The arrangements for the safety of navigation and communications are to be examined to ensure the following safety of navigation and communication objectives have been satisfied:
(a) **Communication Objective**. The ship is to be capable of communication to avert unnecessary danger to itself and other ships in the vicinity during normal and emergency conditions.

(b) **Safety of Navigation Objective**. The ship is to be arranged with the necessary equipment to facilitate safe and effective navigation.
(c) **Equipment Arrangements Objective**. All navigation and communications equipment is to be arranged to allow safe and effective task performance.

4.1.11 **Escape, Emergency Access, Evacuation and Rescue – ERR.** The arrangements for the integration of the requirements for complience with the **FIRE, ESC** and **LSAE** notations are to be examined to ensure that the arrangements support safe and effective task performance.

4.2 Survey

4.2.1 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained for the construction of the ship and machinery.

4.2.2 In addition to 4.1.3, the hull construction of ships is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures.

4.2.3 New ships intended for Classification are to be built under Naval Class Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found so to be, are to be rectified or concession sought from LR.

4.2.4 For compliance with 4.2.3 LR will consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems.

4.2.5 The Surveyor will prepare a report C11(N) record of hull and superstructure watertight, weathertight arrangements and closing appliances.

4.2.6 The date of completion of the Special Survey during construction of ships built under LR's supervision will normally be taken as the date of build to be entered in the *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the *Register Book*.

4.2.7 When a ship, upon completion, is not immediately commissioned but is laid-up for a period, LR, upon application by the Owner, prior to the ship proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery is reported in all respects free from deterioration, in compliance with the Rules, the subsequent Special Survey will date from the time of such examination.

4.3 Existing ships

4.3.1 **Classification of ships not built under LR survey.** The requirements of LR for the Classification of ships which have not been built under LR's Survey are indicated in Ch 3,16. Special consideration will be given to ships that have been designed, constructed and maintained to appropriate standards recognised by the Naval Authority, and to ships transferring Class to LR from another recognised Classification Society who have appropriate Naval Ship Rules.

4.3.2 **Classification of ships built under survey to Classification Rules and Regulations other than LR Naval Ship Rules and Regulations**. The requirements of LR for the Classification of ships and craft which have not been built under LR's Survey to the LR Rules and Regulations for the Classification of Naval Ships are indicated in Ch 3,17.

4.3.3 **Reclassification.** When reclassification or Class reinstatement is desired for a ship for which the Class previously assigned by LR has been withdrawn or suspended, LR will direct that a survey, appropriate to the age of the ship and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the ship be found or placed in a good and efficient condition in accordance with the Rules and Regulations, LR will be prepared to consider reinstatement of the original Class or the assignment of such other Class as may be deemed necessary. The date of any reclassification will be recorded in the Supplement to the *Register Book*. When the original classification was not to the Rules and Regulations for the Classification of Naval Ships, then it will be necessary to demonstrate compliance with the additional requirements of these Rules.

4.3.4 LR reserves the right to decline an application for Classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a ship may retain Class, *see* 1.1.7, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by LR Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyor considers repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to LR's London Office by the Surveyor.

4.4.3 When at any survey it is found that any damage, defect, or breakdown (*see* 1.1.7) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain Class, a suitable Condition of Class is to be imposed by the Surveyors and recommended for consideration. This condition may be designated as an operational defect, under the Owner's control, but LR needs

to be kept advised as to proposed actions. The technical impact of any deficiency on the operational needs of the ship must be considered by the surveyor in liaison with the Owner/Naval Authority before a decision is made with regard to corrective action.

4.4.4 If a ship which is Classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.5 If a ship which is Classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.6 Plans and particulars of any proposed alterations (Mods. or A's and A's) to the approved scantlings and arrangements of the hull, machinery and engineering systems are to be submitted by the Owners or Builders or their representatives for approval by LR and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.5 Existing ships – Periodical Surveys

4.5.1 **Annual Surveys** are to be held on all ships within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded in the Supplement to the *Register Book*. This survey may include optional requirements.

4.5.2 **Intermediate Surveys** are to be held on all ships instead of the third or fourth Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded in the Supplement to the *Register Book*.

4.5.3 The Owner should notify LR whenever a ship can be examined in dry-dock or on a slipway. The maximum period between **Docking Surveys** is not to exceed six years, and should coincide with the Special Survey. Consideration may be given at the discretion of LR to any special circumstances justifying an extension of this interval. A Docking Survey is considered to coincide with the Special Survey when held within the six months prior to the due date of the Special Survey.

4.5.4 The date of the last Docking Survey will be recorded in the Supplement to the *Register Book*.

4.5.5 **In-water Surveys** are to be held concurrent with intermediate surveys. A Docking survey can be carried out in lieu of an IWS Survey. The date of the last In-water Survey will be recorded in the Supplement to the *Register Book*, preceded with the record 'IWS'.

4.5.6 All ships Classed with LR are also to be subjected to **Special Surveys**. These Surveys become due at six-yearly intervals, the first one six years from the date of build or date of Special Survey for Classification as recorded in the *Register Book*, and thereafter six years from the date recorded in the Supplement to the *Register Book* for the previous Special Survey. Consideration can be given, at the discretion of LR, to any exceptional circumstances justifying an extension of hull Classification beyond the sixth year. If an extension is agreed the next period of hull Classification will start from the due date of the Special Survey before the extension was granted.

4.5.7 Special surveys may be commenced at the fifth Annual Survey or anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.8 Special Surveys which are commenced prior to their due date are not to extend over a period greater than twelve months, except with the prior approval of LR.

4.5.9 Ships which have satisfactorily passed a Special Survey will have a record entered in the Supplement to the *Register Book* indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the sixth anniversary.

4.5.10 At the request of an Owner, LR may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of six years between consecutive examinations of each part. In general, approximately one sixth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the six year cycle. Ships which have satisfactorily completed the cycle will have a record entered in the Supplement to the *Register Book* indicating the date of completion which will not be later than six years from the last assigned date of Complete Survey of the hull.

4.5.11 If any examination during Continuous Survey reveals defects, further parts are to opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.12 Alternative arrangements for survey periodicity will be considered by LR upon request. Requests from the Owner, at build or during service, need to be supported by adequate evidence of satisfactory performance before survey periodicity can be changed. These requests could be based upon Reliability Centred Maintenance or other forms of condition monitoring.

4.5.13 Machinery is to be submitted to the surveys detailed in Ch 3,7 to 13.

4.5.14 Complete Surveys of machinery become due at six yearly intervals, the first one six years from the date of build or date of first classification as recorded in the *Register Book*, and thereafter six years from the date recorded in the Supplement to the *Register Book* for the previous Complete Survey. Consideration can be given at the discretion of LR to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the sixth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of LR. On satisfactory completion of a survey, an appropriate record will be made in the Supplement to the *Register Book*. Where the complete survey is completed more than three months before the due date, the new date recorded will be the final date of survey. In all other cases the date recorded will be the sixth anniversary. *See also* 4.5.20.

4.5.15 Upon application by an Owner, LR may agree to the extension of the survey requirements for main propulsion machinery, which, by the nature of the ship's normal service, do not attain the number of running hours recommended by the machinery manufacturer for major overhauls within the survey periods given in 4.5.14.

4.5.16 When, at the request of an Owner, it has been agreed by LR that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed six years. In general, approximately one-sixth of the machinery is to be examined each year. A record indicating the date of satisfactory completion of the Continuous Survey cycle will be made in the Supplement to the *Register Book*. *See also* 4.5.20.

4.5.17 If any examination during Continuous Survey reveals defects, further parts are to opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.18 Upon application by an Owner, LR may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the qualified naval engineering personnel responsible to the Marine Engineer Officer of the ship, followed by a limited confirmatory survey and annual audit of maintenance and repairs records. Particulars of this arrangement may be obtained from LR's London Office. Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may also be obtained from LR's London Office.

4.5.19 Where condition monitoring techniques are applied, LR, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.20 Where machinery installations include a 'lifed item' (an item of machinery, component or equipment necessary for the safety and reliability of propulsion, steering or other essential auxiliary engineering system) which is subject to an overhaul and/or ultimate life limitation, i.e. a period (expressed in operating hours or cycles and/or calendar time) at which the item is to be overhauled or scrapped, the life limitations are to be observed and take precedence over the periodicity of 4.5.14 and 4.5.16 where the life limitation is less than the survey periodicity. Examples may include rolling bearing elements, gas turbines, turbo-chargers, flexible couplings and gear box elements. The manufacturer's maintenance and service instructions are to be strictly observed. Where machinery installations include a 'lifed item' details will be noted in the classification records as a Memorandum (Machinery) record.

4.5.21 Where propulsion and auxiliary machinery is maintained using an approved 'upkeep by exchange' system, the Marine Engineer Officer is to maintain records of all exchanges carried out. At the first convenient opportunity after exchange, a running test on load is to be witnessed by a LR Surveyor (this may typically be the time of annual survey). Where prime movers are maintained by an 'upkeep of exchange' system, details will be noted in the classification records as a Memorandum (Machinery) record.

4.5.22 Boiler surveys, examination of steam pipes and Screwshaft Surveys are to be carried out as stated in Pt 1, Ch 3,11 and 12 of these Regulations. On satisfactory completion, appropriate records will be made in the Supplement to the *Register Book*.

4.5.23 Where the ship is fitted with classed dynamic positioning equipment the system is to be examined annually in accordance with the requirements of Ch 3,2.3.11. In addition a Special Survey is to be carried out at intervals not exceeding five years in accordance with Ch 3,7.2.9.

4.6 Certificates

4.6.1 When survey reports have been received from the Surveyors and approved by LR, a Certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to the Builders or Owners.

4.6.2 A Certificate of Class valid indefinitely subject to endorsement for Annual and Intermediate Surveys, as appropriate, will also be issued to the Owners and a certified copy placed on board. A new certificate will be issued when no further endorsement spaces remain.

4.6.3 LR's Surveyors will issue provisional (interim) certificates, after survey, to enable a ship Classed with LR to proceed on voyage provided that it is in a satisfactory condition. Such certificates will embody the Surveyors' recommendations for continuance of Class, and are subject to confirmation by LR.

4.7 Notice of surveys

4.7.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of Class are carried out at the proper time.

4.7.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a quarterly computer print-out. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of Class.

4.7.3 The Owner will give timely notice of the availability of ships for survey. Should a ship not be available at the due time, the agreement for postponement of the survey should be sought from LR.

4.8 Withdrawal/Suspension of Class

4.8.1 When the Class of a ship, for which the Regulations as regards surveys on the hull, equipment and machinery have been complied with, is withdrawn by LR in consequence of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.8.2 When the Regulations as regards surveys on the hull equipment and machinery have not been complied with and the ship is thereby not entitled to retain Class, the Class will be suspended or withdrawn after consultation with the Owner and a corresponding notation will be assigned.

4.8.3 LR will consider requirements from the Owner to continue Class where operational requirements curtail surveys being held.

4.8.4 When in accordance with 4.4.2 and 4.4.3 a Condition of Class is imposed, this will be assigned a due date for completion and the ship's Class will be subject to a suspension procedure if the condition of Class is not dealt with, or postponed by agreement, by the due date.

4.8.5 When it is found, from the reported condition of the hull or equipment or machinery of a ship, that an Owner has failed to comply with paragraphs 1.1.7, 4.4.1 or 4.4.5, the Class will be liable to be suspended or withdrawn, at the discretion of LR, and a corresponding notation assigned.

4.8.6 When any ship proceeds to sea with a design draught greater than that approved, the Class will be liable to be withdrawn or suspended for the voyage.

4.8.7 In all instances of Class withdrawal or suspension, the assigned notation, with date of application, will initially appear in the Supplement to the *Register Book* and subsequently in the *Register Book*. In cases where Class has been suspended by LR and it becomes apparent that the Owners are no longer interested in retaining LR's Class, the notation will be amended to withdrawn status. After Class withdrawn status has been established in the *Register Book* for one year, it will be automatically amended to 'Classed LR until' (with date).

4.8.8 For reclassification and reinstatement of Class, *see* 4.3.2 and 4.3.3.

4.9 Survey of ships out of commission

4.9.1 The Classification requirements for laid up vessels will be specially considered. Surveys for continuation of Class may be required at the request of the Owners and the discretion of LR.

4.10 Appeal from Surveyor's recommendation

4.10.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to LR, who may direct a Special Examination to be held.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys – annually within three months of the anniversary date.
(b) Intermediate Surveys – in place of the third or fourth annual survey.
(c) Docking Surveys – at six-yearly intervals concurrent with special survey, and in lieu of In-water Survey.
(d) In-water Surveys – concurrent with the Intermediate Survey.
(e) Special Surveys at six-yearly intervals.
For alternative arrangements, *see also* Ch 2,4.5.10, 4.5.11, 4.5.12 and 1.1.2.
(f) Complete Surveys of machinery of six yearly intervals, *see* Ch 2,4.5.14.

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed six years (*see* Ch 2,4.5.10 and 4.5.17).

1.1.3 For the frequency of surveys of machinery, boilers, steam pipes, screwshafts, tube shafts and propellers, *see* Sections 7 to 13.

1.2 Surveys for damage or alterations

1.2.1 At any time when a ship is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult of access are to be specially examined, e.g. if any part of the main or auxiliary machinery, including boilers, or fittings is removed for any reason, the hull structure in way is to be carefully examined, or when cement in the bottom, permanent ballast or sheathing on decks is removed, the structure in way is to be examined before replacement.

1.2.2 This examination should normally be carried out by a Surveyor, and the Owners/Naval Authority should give as much notice as possible to LR so that arrangements can be made for attendance. In the absence of a Surveyor, due to the unforeseen nature of the removal, the Owner is to carry out a suitable examination and report the findings to LR as soon as practicable.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys .

1.3.2 In the event of significant damage or defect affecting any ship, LR reserves the right to perform unscheduled surveys of the hull of other similar ships classed by LR and deemed to be vulnerable.

1.3.3 A requirement to perform an unscheduled survey will be subject to the agreement of the Owner and operational needs.

1.4 Documentation

1.4.1 The Owner may wish to retain the originals of certificates issued by LR, however, Naval ships are required to carry the following documentation on board so that the attending Surveyor is able to carry out his duties (certified copies of certificates are acceptable):

(a) Endorsable Certificate of Class.
(b) C11(N) – Record of watertight and weathertight closing arrangements.
(c) Approved Stability information and damage control plan. and the following as applicable.
(d) Lifting Appliances Certificate.
(e) Pollution record of equipment.
(f) Tonnage Certificate.
(g) Safety Equipment Certificate and associated report.
(h) Fire control plan.

1.5 Definitions

1.5.1 **Spaces** are all separate compartments within the hull and superstructure including plated masts. Integral tanks are considered to be separate spaces.

1.5.2 **Representative Spaces** are those which may be expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces account should be taken of the service and repair history onboard and identifiable critical areas.

1.5.3 **Critical Areas** are locations which are known to be vulnerable to corrosion, buckling and/or fatigue cracking. These will be identified at the plan approval stage.

1.5.4 **Suspect Areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed ships, areas of the bottom structure forward prone to slamming damage.

1.5.5 For ships designed to the *Rules and Regulations for the Classification of Ships*, Substantial Corrosion is defined as wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.6 For ships designed on a net scantling basis (using for example the *Rules and Regulations for the Classification of Naval Ships*) Substantial Corrosion is defined as the wastage of individual plates and stiffeners in excess of the net scantlings, less an allowance for rolling, but within corrosion limits that are applicable for the structure concerned.

1.5.7 **Excessive Corrosion** is wastage in excess of acceptable limits that are applicable for the structure concerned.

1.5.8 **Protective Coatings** for steel ships should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.9 Coating conditions for steel ships are defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting affecting 20 per cent or more of areas under consideration.

POOR condition with general breakdown of coating affecting 20 per cent or more of areas under consideration or hard scale affecting 10 per cent or more of the area under consideration.

■ *Section 2* Annual Surveys – Hull, machinery and optional requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant maintenance period and in consultation with the Owner with regard to operational needs.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull, so far as necessary and practicable, in order to be satisfied as to its general condition.

2.1.3 Particular attention is to be paid to critical areas.

2.2 Hull

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of doors, hatchways and lifts on upper and superstructure decks, weather deck plating and air pipes, exposed casings, deckhouses, superstructure bulkheads, side, bow and stern doors, windows, side scuttles and deadlights,guard rails, life-lines, ladders, pressure relief plates and other openings, together with all closing appliances and flame screens.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks.

2.2.2 Any hatch covers and coamings together with any doors, lifts or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.

(a) Mechanically operated lifts, hatch covers or doors are to be tested for tightness to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms. Associated drainage channels and operating mechanisms, such as tracks and wheels, are also to be examined to confirm they are in satisfactory condition.

(b) Hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

This examination will include hatches and doors in superstructures.

2.2.3 The anchoring and mooring equipment is to be examined so far as is practicable.

2.2.4 The watertight doors/closures in watertight bulkheads and any indicators or alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.5 The Surveyor is to be satisfied regarding the draught marks on the ship's side.

2.2.6 The Surveyor is to be satisfied that no alterations have been made to the ship which affect stability and strength.

2.2.7 The surveyor is to check the C11(N) on board the vessel and verify with the actual arrangement on board.

2.2.8 For steel ships, the requirements of 3.2.2 and 5.4.2 regarding the survey of water ballast spaces, compensated fuel tanks, integral sanitary tanks and bilges are also to be complied with as applicable.

2.2.9 The Surveyor is to carry out a Close-up Survey and thickness measurement of structure identified at the previous Special Survey as having substantial corrosion.

2.2.10 The first Annual Survey should include a review of the year's service, taking into account feedback from the Owner. Special attention needs to be given to areas of the structure where defects have become apparent. It is important that this information is fed back to the Design Authority and building yards for follow-on ships.

2.3 Machinery

2.3.1 The Surveyor is to generally examine the machinery and boiler spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are adequately identified and free of obstruction.

2.3.2 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.3.3 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.3.4 The bilge pumping and dewatering systems and bilge wells, including operation of extended spindles and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps and dewatering eductors is to be proven, including access to all bilge areas.

2.3.5 Piping systems containing oil fuel, lubricating oil or other flammable liquids are to be generally examined and operated as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding devices.

2.3.6 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the non-metallic joint are below the deepest waterline.

2.3.7 The Surveyor is to be satisfied regarding the following items associated with machinery installations.

(a) Locking arrangements for locked valves and inspection covers.

(b) Integrity of guards for rotating machinery.

(c) Lighting arrangements, particularly at control and instrumentation panels.

(d) Operation of automatic start-up of pumps and systems for essential systems where they are required by the Rules.

(e) Condition of machinery securing and mounting arrangements.

(f) The condition of bulkhead glands.

2.3.8 The boilers, other pressure vessels and their accessories and associated fittings including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.3.9 Records of boiler treatment and analyses are to be retained on board and audited annually by the LR Surveyor. The water treatment and results of analyses are to be in accordance with the manufacturer's recommendations.

2.3.10 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions as far as is practicable. Particular checks are to be made on the integrity of electrical enclosure and cleanliness of switchboards and bus bars. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode.

2.3.11 Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.3.12 For ships having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified. The Surveyor is to be satisfied regarding the efficient condition of bilge level detection and alarm systems on ships assigned a **UMS** notation.

2.3.13 For ships fitted with a classed dynamic positioning system and/or classed thruster assisted positional mooring system the control system and associated machinery items are to be generally examined and tested under operating conditions to an approved Test Schedule.

2.3.14 For ships fitted with positional mooring equipment in accordance with the Rules, a schedule or rota of moorings to be examined at Annual Survey should be agreed for component parts of the positional moorings.

2.4 Other notations

2.4.1 Where the options described in 2.4.2, 2.4.4 and 2.4.6 are required by the Owner, a notation will be assigned and surveys are to be included with the Annual Survey.

2.4.2 **Fire Protection (FIRE)**. The arrangements for fire protection, fire detection and extinction are to be examined and are to include the following items:

(a) Verification, so far as is reasonably practicable, that no significant changes have been made to the arrangements for fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted;
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of the water fire-fighting system, and confirmation that each pump connected to the water fire fighting system, including any emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems, controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests, including operational alarm tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is reasonably practicable, that the remote control for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, hatches and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.

2.4.3 **Escape and Emergency Access (ESC).** The arrangements for escape of personnel and emergency access are to be examined and are to include the following:

(a) Verification, so far as is reasonably practical, that no significant changes have been made to the arrangements for escape and emergency access.
(b) Verification that all normal and emergency escape and emergency access routes are free of obstruction.

2.4.4 **Life Saving and Evacuation Arrangements (LSAE)** The arrangements for life saving and evacuation are to be examined and are to include the following:

(a) Verification, so far as is reasonably practicable, that no significant changes have been made to the arrangements for life saving and evacuation.
(b) Verification of Life-jackets, Life-buoys, Immersion Suits, Thermal Protection Aids, etc. and their attachments for effectiveness and condition.
(c) That rescue boats and survival craft have been serviced by an approved servicing company, and ascertain that they are identified and certificated with a valid date.
(d) That the rescue boat and launching/recovery arrangements are in full working order.
(e) The the survival craft launch arrangements, are in a good working order.

2.4.5 **Safety of Navigation and Communication (SNC)** The arrangements for navigation and communication equipment are to be examined and are to include the following:

(a) Verification, so far as is reasonably practicable that no significant changes have been made to the navigation and communication equipment.
(b) That the ship is in possession of up-to-date Nautical Publications, Emergency Instructions, International Code of Signals, Operating Instructions for Life-saving Appliances and their maintenance.
(c) Shipboard navigational equipment.
(d) Signalling equipment (lights and sounds).
(e) Navigation lights.
(f) Rockets and signals (pyrotechnics).
(g) Black shapes.

2.4.6 **Pollution Prevention (POL)** The arrangements for pollution prevention are to be examined and are to include the following:

(a) **Oil.** Verification of piping system arrangements between tanks, bilge and ballast systems, which are used to transfer oil/oily water and ballast water to ensure that no changes have been made to the systems since they were installed. Checking oil filters, oily water separators and sludge/oily water residue containment.
(b) **Sewage.** Verification of the sewage treatment arrangements, containment and the piping systems.
(c) **Garbage.** Verification of the garbage disposal arrangements and the installation of the equipment to ensure that no unauthorised changes have been made.
(d) **Air.** Verification that the engine exhaust emissions are still within the NO_x Technical Code.
Verification of the incinerator installation.
Re-testing the fuel oils to ensure that the sulphur content is still below 4,5 per cent.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with any relevant maintenance period wherever practicable, *see* 2.1.1.

3.2 Hull

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 For steel ships a general examination of salt water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.8. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of Class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all ships over six years of age and up to 12 years of age, representative salt water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.8, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel ships over twelve years of age all salt-water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all ships over twelve years of age the anchors are to be partially lowered and raised using the capstan/ windlass.

3.2.4 Representative internal spaces including fore and aft peak spaces, plated masts, machinery spaces, bilges, etc., are to be generally examined. These spaces should include all suspect areas, *see* 1.5.4.

3.2.5 The Surveyor is to carry out a Close-up Survey and thickness measurement of the structure identified at the previous Special Survey as having substantial corrosion.

3.3 Machinery

3.3.1 Machinery and boiler spaces including tank tops, bilges and cofferdams, sea suctions and overboard discharges are to be generally examined.

3.3.2 Areas deemed dangerous, such as magazine spaces and spaces where low flash point oils are stored and handled and compartments adjacent to such spaces are to be examined for the following type:

(a) Defective and non-certified safe electrical equipment.
(b) Improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through dangerous spaces is to be carried out.

3.3.3 Electrical generators are to be examined under working conditions to verify compliance with Vol 2, Pt 10, Ch 1,2.

■ *Section 4*
Docking Surveys and In-water Surveys

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the ship and machinery so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a ship is in dry-dock or on a slipway it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering, abrasion or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where fitted, the satisfactory condition, attachment and operation of the cathodic protection (active or passive) is to be confirmed.

4.2.5 The sea connections and overboard discharge valves, their attachments to the hull and the gratings, at the sea inlets are to be examined. References must be made to the C11(N) document carried on board.

4.2.6 The clearances of the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor, rudders and stabilisers are to be lifted for examination of the stock. The securing of rudder and stabiliser couplings is to be confirmed.

4.2.7 Special attention is to be given to the hull in way of underwater fittings such as thrusters, shaft brackets, stabilisers, rudders, rope guards, eddy plates, GRP domes, bilge keels, echo sounders, and their attachments.

4.2.8 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi-hull ships.

4.2.9 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.6 and Table 3.5.1.

4.2.10 For Surface Effect Ships any flexible skirts together with their attachment are to be examined.

4.2.11 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.2.12 The Surveyor is to verify all draught markings as applicable at the time of dry-docking.

4.2.13 When Machinery Naval Class has been adopted, the following items are additionally applicable. The work is to be carried out in accordance with maintenance manuals and the manufacturer's recommendations for servicing and renewals observed.

(a) The propeller and fastenings are to be examined. (Where a controllable pitch propeller is fitted, examination is to include blade fastenings and hub). The sternbush is to be examined as far as practicable.
(b) Where propeller shafts are wrapped for corrosion protection, the condition of the wrapping is to be confirmed.
(c) The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearing is to be ascertained.
(d) The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed. Where inflatable shaft seals are fitted, their condition and operation is to be verified.
(e) Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as practicable.
(f) Where podded propulsion units are fitted, the bearings and sealing arrangements, steering ring and thrust bearings in the hull are to be examined as far as practicable.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey between Special Surveys, as a Docking Survey, where suitable protection is applied to the underwater portion of the hull. If requested, an IWS record may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with.

4.3.2 The In-water Survey is to provide the information normally obtained from the Docking Survey, *see* 4.2.2 to 4.2.13.

4.3.3 The underwater part of the hull should be marked with search lines for reference purposes.

4.3.4 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the ship in sheltered waters. The in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory by use of CCTV. There is to be good two-way communication between the Surveyor and the diver.

4.3.5 Diving and In-water Survey operations are to be carried out by companies recognised by LR. Continued recognition by LR will be dependent on the standard of workmanship by the company being maintained to the satisfaction of LR's Surveyors.

4.3.6 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may, in consultation with the Owner, require that the ship be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.7 Where a vessel has an IWS record, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the IWS record can be maintained.

■ *Section 5*
Special Survey – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of 4.2 is to be carried out as part of the Special Survey.

5.2 Preparation

5.2.1 The ship is to be prepared for survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with Table 3.5.1, the ship is opened out by removal of linings, etc., and defects are found, further opening out may be required in order that the Surveyor can confirm the full extent of the defects.

5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined, *see also* 5.4.1 for tank examinations on steel ships. Special attention is to be paid to any suspect areas, *see* 1.5.4. and Table 3.5.1.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. (It should be noted that 'Replenishment at Sea' has the potential of imposing greater pressures on tank boundaries than that normally met in service). Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, masts and superstructures are to be examined.

5.3.5 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

Table 3.5.1 Survey preparation

Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old) and subsequent special surveys
(1) All spaces in the ship are to be cleared and cleaned as necessary, including all bilge spaces in order that the Surveyor may be satisfied as to the condition of the structure, see 1.5.3 and 1.5.4. A record is to be made of where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments are to be cleared and cleaned as necessary, and the bilges cleaned and prepared for examination. Floor plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In ships having wood decking or sheathing, and in refrigerated stores, a sufficient amount of material covering the structure is to be removed for access and examination. The amount of removal will depend upon the condition found and will be to the Surveyor's satisfaction. (4) Tanks are to be cleaned as necessary in order to satisfy the requirements of Table 3.5.2.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudders are to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Samples of lagging and lining are to be removed in order that the Surveyor may be satisfied as to the condition of the structure. (2) All wood decks and sheathing, or other covering, on steel decks are to be removed in order to ascertain the condition of the structure.

NOTES
1. These requirements can be amended to reflect proven information concerning the performance of structure through an Owner's maintenance system such as 'Reliability Centred Maintenance'.
2. Where permanent ballast is fitted, samples of ballast are to be removed for examination of the structure underneath. The condition of the exposed structure is to be to the satisfaction of the Surveyor.

5.3.6 The anchors are to be examined, the chain cables are to be ranged and they are to be examined together with the chain locker (*see* Table 3.5.1) and clench plate. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. Cables are to be changed ‘end-for-end’. Anchor handling arrangements are to be examined.

5.3.7 Representative fastenings on the weatherdecks, e.g. for guardrails and spurnwaters, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.8 When applicable, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew spaces, and spaces in which crew are normally employed.

5.4 Examination and testing – Additional items for steel ships

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 3.5.2.

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in 1.5.8 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses, is to be examined and the efficiency of the insulation arrangements confirmed.

5.5 Examination and testing – Additional items for composite ships

5.5.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.5.2 The hull to deck joint, together with any joints between the deck and deckhouses or superstructures, are to be examined.

5.5.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, capstan/windlass, shaft brackets, fendering, mooring bitts, etc is to be examined.

Table 3.5.2 Tank internal examination requirements for steel ships

Tank	Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old)	Special Survey IV (Ship 24 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 1	*See* Notes 1 and 2	All tanks
Fresh water	None	*See* Note 1	*See* Notes 1 and 2	*See* Notes 1 and 2	All tanks
Oil fuel	None	*See* Note 1	*See* Notes 1 and 2	*See* Notes 1 and 2	All tanks
Oil Fuel (compensated)	*See* Note 1	All tanks	All tanks	All tanks	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel, fresh water, oil fuel and water ballast, avcat or lubricating oil need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing, and from an internal examination of two representative tanks. (These representative tanks should change from survey to survey).
2. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.
3. Particular care must be taken in examining structure under suctions.
4. Where testing is required, a functional test may be acceptable at the Surveyor’s discretion.

■ *Section 6*
Special Survey – Thickness measurement requirements for steel ships

6.1 General

6.1.1 The Surveyor may require measurements of thickness of the material to be taken in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Particular attention is to be given to the structure in way of discontinuities.

6.1.2 Thickness measurements, as required by Table 3.6.1, are to be carried out in accordance with the following requirements.

6.1.3 Measurements are to be taken at the forward and aft areas of shell plates. A number of readings should be taken in a local area, and averaged to provide the recorded reading. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are to be renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.4 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a company qualified as Grade 1 or Grade 2 according to Lloyd's Register's (hereinafter referred to as 'LR') Approval for Thickness Measurement of Hull Structures, or by a suitably qualified Surveyor.

6.1.5 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the company carrying out the thickness measurements.

(a) The work of companies having Grade 1 approval is subject to check testing by the Surveyor.
(b) Thickness measurements by companies having Grade 2 approval are to be carried out with the Surveyor substantially in attendance.

6.1.6 Thickness measurements may be carried out in association with the fifth Annual Survey.

6.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 3.6.1 Thickness measurement of steel ships

Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old)	Special Survey IV and subsequent (Ship 24 years old and over)
(1) Bottom and lower parts of chain locker. (2) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) Wind and water strakes in way of 0,5*L* amidships. (2) Bottom and lower parts of chain locker. (3) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) Weatherdeck plating under wood deck planking or sheathing. (2) Shell plating in way of the waterline throughout the length of the ship. (3) Two complete transverse sections of deck and shell plating within 0,5*L* amidships, one of which should be in way of a machinery space. (4) Bottom and lower parts of chain locker. (5) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) All weatherdeck plating outside deckhouses or superstructures and including plating under wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the ship. (3) Two complete transverse sections of deck and shell plating within 0,5*L* amidships, one of which should be in way of a machinery space. (4) Bottom and lower parts of chain locker. (5) Critical and Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Bottom shell in way of any cement, asphalt, ballast or other composition. (c) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces and any other wet spaces. (d) Structure in way of integral sanitary tanks.
NOTE *See* 1.5.8 for the definition of GOOD condition.			

6.2 Thickness measurement reporting

6.2.1 Thickness measurement is normally carried out by approved companies who are required to report their findings to LR as follows.

6.2.2 A report is to be prepared by the approved company carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.3 The thickness measurement report is to be verified and signed by the Surveyor, and included with the Surveyor's report.

■ *Section 7* Machinery survey – General requirements

7.1 Annual, Intermediate and Docking Survey

7.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

7.2 Complete Survey

7.2.1 While the ship is in dry-dock, all openings to the sea in the machinery spaces, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 13), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.3 An examination is to be made of all reduction gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated brake and clutch arrangements where fitted.

7.2.4 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.
(e) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.

7.2.5 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.6 The valves, cocks and strainers of the bilge and salvage system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also the ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.7 Fuel tanks which do not form part of the ship's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

7.2.8 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.9 On vessels fitted with a classed dynamic positioning system the control system and associated machinery items are to be examined and tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for steam and gas turbines, oil engines, electrical installations and boilers are given in Sections 8, 9 10 and 11 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, LR will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records.

7.2.11 Where machinery installation include a 'lifed item' the requirements of Ch 2,4.5.21 are applicable.

■ *Section 8* Turbines – Detailed requirements

8.1 Complete Survey

8.1.1 The requirements of Section 7 are to be complied with.

8.1.2 The following parts are to be opened out and examined:

The working parts of the main turbines and of auxiliary machinery used for essential services, including bulkhead stop valves, manoeuvring valves, the blading, rotors, flexible couplings and casings.

8.1.3 In gas turbines the following parts are to be opened out and examined:

The impellers or blading, rotors and casings of the air compressors, the combustion chambers, burners, intercoolers, heat exchangers, gas and air piping and fittings, starting and reversing arrangements.

8.1.4 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for essential services, are to be examined to the satisfaction of the Surveyor, and if it is considered necessary, they are to be tested.

8.1.5 The manoeuvring of the turbines is to be tested under working conditions.

8.2 Turbine condition monitoring (TCM)

8.2.1 Where the main propulsion steam turbines are provided with approved vibration monitoring equipment, a machinery notation **TCM** (Turbine Condition Monitoring) may be assigned provided that the following conditions are complied with:

(a) Vibration measurements recorded with equipment acceptable to LR are to be taken at regular intervals not exceeding six months. The records are to be retained on board and be available to the LR Surveyors for assessment at time of survey.

(b) Rotor position indicators are to be installed permanently on each turbine. Records of these readings are to be retained on board the ship for inspection by the LR Surveyor at time of survey.

8.2.2 For maintenance of the **TCM** notation, the records of vibration monitoring and rotor position readings are to be audited annually.

8.2.3 In addition to the vibration readings at the time of the survey, it is necessary to carry out a full power trial to demonstrate to the LR Surveyor that the turbines are in good working order.

8.2.4 Where the notation **TCM** has been assigned the main steam turbine top casings need not be lifted for examination of the rotors and diaphragms as required by 8.1.2 provided the condition monitoring data is found within limits set by acceptance standards. The remaining requirements of 8.1.2 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction, the top casing will be required to be lifted.

■ *Section 9*
Oil engines – Detailed requirements

9.1 Complete Survey

9.1.1 The requirements of Section 7 are to be complied with.

9.1.2 The following parts are to be opened out and examined:

Cylinders, covers, valves and valve gear, pistons and piston rods, crossheads, guides, connecting rods and crankshafts and all bearings, crankcases, bedplates, entablatures, crankcase door fastenings and explosion relief devices, scavenge relief devices, scavenge pumps, scavenge blowers, superchargers and their associated coolers, air compressors and their intercoolers, filters and/or separators and safety devices, fuel pumps and fittings, camshaft drives and balancer units, vibration dampers or detuners, flexible couplings and clutches, reverse gears, attached pumps and cooling arrangements.

9.1.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors. This requirement is only applicable to oil engines using compressed air directly into individual cylinders through starting air valves, it is not applicable to air motor starting systems.

9.1.4 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

9.1.5 Where steam is used for essential purposes, the condensing plant, feed pumps and oil fuel burning plant are to be examined and the steam pipes examined and tested as detailed in Section 12.

■ *Section 10*
Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The requirements of 2.3 and 3.3 are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 10.2.1. The Surveyor is also to be satisfied regarding the condition of glands at watertight and gastight bulkheads.

10.2.5 The generator prime movers are to be surveyed as required by Sections 8 and 9 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.6 Where transformers associated with supplies to essential services are liquid immersed, the Owner is to arrange for samples of the liquid to be taken and tested for breakdown voltage, acidity and moisture, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

10.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.10 Where the ship is electrically propelled, the propulsion motors, generators, conversion equipment, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil if used, is to be tested in accordance with 10.2.6. Interlocks intended to prevent unsafe operations or unauthorized access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.11 A General Examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe type electrical equipment has not been impaired owing to corrosion, missing bolts, etc., and that there is not an excessive build-up of dust on or in dust protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

■ *Section 11* **Boilers**

11.1 Frequency of survey

11.1.1 All boilers, economizers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for essential services, together with boilers used exclusively for non-essential services having a working pressure exceeding 3,4 bar and a heating surface exceeding 4,65 m^2 are to be surveyed at intervals not exceeding 3 years and generally examined externally at the time of the Annual Survey of the ship.

11.2 Scope of surveys

11.2.1 At the surveys described in 11.1 the boilers, superheaters, economizers and air heaters are to be examined internally and externally and where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thickness of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers, superheaters and economizers are to be opened up and examined and the safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable provided that the valves lift at not more than 103 per cent of the approved design pressure. The remaining mountings are to be examined externally and if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

11.2.2 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

11.2.3 The oil fuel burning system is to be examined under working conditions and a General Examination made of fuel tank valves, pipes, deck control gear and oil discharge pipes between pumps and burners.

11.2.4 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in Section 12.

11.2.5 At the Annual General Examination referred to in 11.1.1 the requirements of 2.3.7 and 2.3.8 are to be complied with.

■ *Section 12* Steam pipes

12.1 Frequency of survey

12.1.1 Saturated steam pipes, also superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450ºC, are to be surveyed 12 years from the date of build (or installation) and thereafter at six-yearly intervals.

12.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450ºC are to be surveyed after six years from the date of build (or installation) thereafter at six-yearly intervals.

12.1.3 At 12 years from the date of build (or installation) thereafter at six-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea, are to be hydraulically tested to twice the working pressure.

12.2 Scope of surveys

12.2.1 At each survey a selected number of main steam pipes, also of auxiliary steam pipes, which:
(a) are over 76 mm external diameter;
(b) supply steam for essential services at sea; and
(c) have bolted joints,
are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as is practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of the surveys all sections of the pipeline will be tested.

12.2.2 Where main and/or auxiliary steam pipes of the category described in 12.2.1(a) and (b) have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in the way of the welds is to be removed, and welds examined and if considered necessary by the Surveyor, crack detected. Pipe ranges having welded joints are to hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

12.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipe adjoining and cross-connecting these headers in the smokeboxes are, at the surveys required by 12.1 to be included in the pipes selected for examination and testing as defined in 12.2.1. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only to be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and if he considers it necessary, a sample pipe is to be removed for examination.

12.2.4 At the surveys specified in 12.1.3, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, also closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

12.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, LR will be prepared to consider postponement of the survey, either wholly or in part.

■ *Section 13* Screwshafts, tube shafts and propellers

13.1 Frequency of surveys

13.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of six years when the keyway complies fully with the present Rules.

13.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of six years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

13.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of six years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

13.1.4 All other shafts not covered by 13.1.1 to 13.1.3 are to be surveyed at intervals of 3 years.

13.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

13.1.6 Directional propeller and podded drive units for main propulsion purposes are to be surveyed at intervals not exceeding six years.

13.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding six years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

13.1.8 Dynamic positioning and/or thruster assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding six years.

13.2 Normal surveys

13.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 13.1.1 to 13.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

13.2.2 Directional propeller and podded drive units are to be dismantled for examination of the propellers, shafts, gearing, control, electrical and monitoring equipment.

13.2.3 Water Jet Units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

13.2.4 Dynamic positioning and/or thruster assisted mooring and athwartship thrust propellers are to be generally examined so far as is possible in dry-dock and tested under working conditions afloat for satisfactory operation.

13.3 Screwshaft Condition Monitoring (SCM)

13.3.1 Where oil lubricated shafts with approved oil glands are fitted, a machinery notation **SCM** (Screwshaft Condition Monitoring) may be assigned provided that the following conditions are complied with:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
   - (i) Water content.
   - (ii) Chloride content.
   - (iii) Bearing material and metal particles content.
   - (iv) Oil ageing (resistance to oxidation).

   Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(b) Oil consumption is to be recorded.

(c) Bearing temperatures are to be recorded, (two temperature sensors or other approved arrangements are to be provided).

(d) Facilities are to be provided for measurement of bearing weardown.

(e) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

13.3.2 For maintenance of **SCM** notation, the records of analyses, consumption and temperature, together with weardown readings are to be retained onboard and audited annually.

13.3.3 Where the notation **SCM** has been assigned the screwshaft need not be withdrawn at surveys as required by 13.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 13.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 13.2.1.

13.4 Modified Survey

13.4.1 A Modified Survey may be accepted at alternate six-yearly surveys for shafts described in 13.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 13.1.2 and 13.1.3.

13.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

13.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

13.4.4 Where the notation **SCM** has been assigned as described in 13.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

13.5 Partial Survey

13.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, LR will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

13.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

13.5.3 LR will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 14* Hull planned maintenance, HPMS

14.1 Introduction

14.1.1 Within the scope of Ch 2,4.5.12 an approved Hull Planned Maintenance Scheme (HPMS) can be accepted as an integral part of LR's Continuous Survey (CSH) cycle.

14.1.2 The following improved facilities for dealing with hull structural surveys are provided through adoption of the Hull Planned Maintenance Scheme:

(a) A more flexible approach to dealing with Classification Surveys of selected hull structural items. Opening out for Classification inspection is restricted to mandatory items and to verify the efficiency of the scheme through annual and periodical audits. The condition as observed and reported by the ship's LR authorised staff will, subject to Annual Audit, be sufficient to credit the items for survey.

(b) The Navy can operate a single system, covering maintenance, spare parts/ consumables supply and survey requirements for both hull and machinery items. The level of documentation and control will demonstrate a commitment to any Naval Authority requirements.

14.1.3 The Hull Planned Maintenance Scheme will operate by allowing LR authorised personnel to carry out inspections of selected hull items to an approved schedule of inspections over a six year period corresponding to the naval ship classification cycles. Ships currently undertaking classification surveys by either SS or CSH regimes may be accepted onto the Scheme. In order to implement the scheme it will be necessary to divide the items selected for ship's staff inspection into a programme similar to that required for CSH in which approximately 17 per cent of hull master list items are inspected each year. In preparing this schedule of inspections, due account should be taken of the items still required to be surveyed by an LR Surveyor such that these may be conveniently carried out at the time of the Annual Audit or on completion of the CSH classification cycle.

14.2 Master list Items

14.2.1 A list of typical hull master list items that can be surveyed by authorised personnel, and those items that remain to be dealt with by LR Surveyors, can be obtained from LR's London Office. It should be noted that LR will continue to inspect, as necessary, where there is a history of structural defects in a particular area, either on the ship or on a similar ship.

14.2.2 Where protective coating condition has been found to be poor or where substantial corrosion is identified in a tank or space scheduled for inspection by ship's staff, a Memorandum will be imposed requiring that area to be examined and gauged at Annual Surveys by an LR Surveyor. Notwithstanding this requirement, the tank or space in question may continue to be inspected by the ship's staff subject to the agreement of the Scheme Manager.

14.3 Scheme Approval

14.3.1 It is recognized that planned maintenance systems may take various forms; the type of maintenance control, the scheduling, reporting and recording methods can only be decided by the Navy, having due regard to all the factors involved.

14.3.2 Approval of the planned maintenance scheme involves approval of the overall approach to maintenance for each installation, not just approval of the planned maintenance software. The amount of information to be submitted, however, can be reduced if the planned maintenance software has been approved using LR's *Software Conformity Assessment Scheme.* Further details can be obtained from LR's local offices.

14.3.3 Operational requirements for the approval of Hull Planned Maintenance Schemes are as follows:

(a) Ship to be operating the Continuous Survey Cycle for Hull **(CSH).** (Where the Naval Authority requirements preclude the operation of the ship on a continuous hull survey, an alternative arrangement of 'modified' Special Survey will be employed.)

(b) Ship to be operating an approved Machinery Planned Maintenance Scheme.

(c) All personnel operating the scheme to hold a valid LR *Certificate of Authorisation.*

(d) The language of the scheme is to be English.

(e) The scheme is to be based on a computerised system and should have back-up devices, which are to be updated at regular intervals.

(f) Access to computerised systems for updating of the maintenance documentation and maintenance programme shall only be permitted by personnel with a valid LR *Certificate of Authorisation.*

(g) Approval of the scheme is required to be reconsidered if ownership or management of the ship changes.

14.3.4 Details to be submitted:

(a) A description of the scheme regarding its application on board ship and the proposed flow of maintenance documents and method of filing.

(b) A numbered index of the items is to be included in the scheme. This index is to include at least all hull items that appear on the 'Master List of Surveyable Items'. The scheme may also cover items that are not required for classification. The indexing system is to be such that ready cross-reference to the Master List numbers can be made.

(c) Sample job descriptions, and the time schedules for each item, are to be provided. Maintenance descriptions are to cover at least the minimum work necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A selection of sample job descriptions will suffice to demonstrate how the system works.

(d) The reporting and recording procedures are to be sufficiently comprehensive to demonstrate that both the Navy and the LR Surveyor can verify correct operation of the planned maintenance scheme at the time of the Annual Audit. There is to be a system for reporting the following information to Navy and recording on board ship and at the Navy's headquarters:
- details of inspections carried out;
- the condition as found;
- any repairs or maintenance undertaken.

(e) The details of items inspected may be supplemented with digital photographs. These may be stored within the planned maintenance software or in a clearly distinguished and labelled electronic file system.

14.3.5 Where a ship is already operating an SS classification regime it will be necessary for the survey cycle to be converted to a CSH regime. Adoption of the scheme is best effected at the commencement of the next SS/CSH classification cycle. However, where a Navy wishes to enter the scheme in mid cycle this can be achieved by the following methods:

(a) Entry up to 2nd Annual Survey:
all hull master list items will require to be dealt with between date of entry and the SS/CSH due date;

(b) Entry following 2nd Annual Survey:
at least 17 per cent of the hull master list items to be dealt with in each full year of the SS/CSH cycle remaining, part years to be dealt with pro rata. The balance of hull master list items to complete the SS/CSH cycle will be dealt with by the LR Surveyor at SS/CSH due date.

14.3.6 Where entry is effected following the 2nd Annual Survey, the Navy may chose to deal with more than the minimum number of items as indicated above, in which case the number of items remaining to be dealt with by the LR Surveyor to complete the SS/CSH cycle can be reduced accordingly.

14.4 Roles and Responsibilities

14.4.1 **Navy.** The Navy should make a request for approval of the planned maintenance scheme either through a local LR office or direct to the London office. The information detailed in 14.3.4 should be submitted. Requests for approval of planned maintenance software in accordance with *LR's Software Conformity Assessment Scheme* should be made to a local LR office or direct to the London office.

14.4.2 **Lloyd's Register.** The planned maintenance scheme will be reviewed and, if acceptable, a *Certificate of Operation* of an Approved Planned Maintenance Scheme for Hull Structures will be issued to the Navy. A copy of the Certificate is to be retained on board the subject ship for the information of the Commanding Officer, Marine Engineer Officer and LR's Surveyors. The **HPMS** notation will be assigned if requested and an appropriate memoranda item entered on the ship's survey status. The *Certificate of Operation* will be valid until the end of the classification cycle and, on completion of a satisfactory audit, the attending Surveyor will reissue the certificate.

14.4.3 **Lloyd's Register Scheme Manager.** A Scheme Manager will be appointed by LR for each Navy with ships operating the Hull Planned Maintenance Scheme. The Scheme Manager will administer the scheme on an individual ship or group basis, act as a technical consultant to the Navy and train the ships' staff in the methods of hull structural inspection and reporting. He/she will be resident in either a terminal port that the ship uses regularly or the LR office that manages the Navy's account. More details are given in the following paragraphs:

(a) Scheme Set-up
The Scheme Manager will, on obtaining a request from a Navy to include a ship on the Scheme:
- Identify the ship(s) to be assessed with the Navy.
- Contact LR's London Office for any special requirements. For example there may be specific areas where LR will not credit inspections by a ship's staff due to a history of defects.
- Guide the Navy through completion of the Hull Planned Maintenance Scheme implementation check list and application form.
- Review ship's Master List of surveyable items to determine which items will be inspected by ship's staff.
- Liaise with the Navy to determine a schedule of inspections to include the items to be inspected by a ship's staff and taking due account of the items still required to be surveyed by an LR Surveyor.
- Obtain scheme approval from LR's London Office.
- Issue certification for the ship (i.e. *Certificate of Operation*).

(b) Training
The Scheme Manager will carry out the following actions associated with training:
- Prepare training documentation and training workshops.
- Deliver training to the ship's staff and issue certification (i.e. *Certificate of Authorisation*).
- Maintain the database of authorised ship's officers, available through CDLive.
- Arrange for refresher training programmes for the ships' staff at 6 yearly intervals.

(c) Scheme Operation
During operation, the Scheme Manager will act as the primary contact for Hull Planned Maintenance issues:
- Confirm operation of the scheme through contact with the Navy's office.
- Review and process ship's staff reports.
- Perform, where practicable, shipboard Annual Audit of the scheme.
- Where the shipboard Annual Audit is undertaken through another LR office, act as liaison and contact point for the local LR Surveyor.

- To assess progress of the scheme at the end of each survey cycle and report to London Office and the Navy. Undertake a review at the end of the second survey cycle, i.e. when the ship is 12 years of age, and, if applicable, make a recommendation to the Classification Group in London that the ship be considered for extension of the scheme into the third cycle.

14.4.4 **Authorised Ship's Personnel.** Authorised ship's personnel will carry out inspections of the hull structural items for which they are authorised, at sea or in port, whichever is the most convenient. Inspections of individual master list items are required to be carried out in accordance with the applicable requirements of *LR's Rules and Regulations for the Classification of Naval Ships.* The Commanding Officer and Navy should arrange for LR's Surveyors to carry out an Annual Audit of the hull maintenance records. Annual audits are to be held within three months before or after the due date and are to be harmonised with the Annual Classification Survey. Items to be credited for Class can be CSH items that have become due in the previous 12 months. In the case of new ships on their first survey cycle, approximately 17 per cent of the total number of CSH items are to be selected.

14.4.5 Requirements of the Intermediate Special Survey **(ITSS)** will still require to be satisfied, as applicable. Master list items dealt with by the ship's staff in the 12 months prior to ITSS may be considered for credit towards this survey and may not need to be re-examined by the LR Surveyor unless required as part of the Annual Audit.

14.4.6 At the Annual Audit, the maintenance records and associated documentation are to be made available, which should include:

- Inspection and maintenance records for each item to be credited for Class. These records should give details of any repairs carried out.
- Written details of any breakdown, malfunction or defect in hull structure. Such details should include the main cause of failure.
- An LR *Certificate of Authorisation* for all authorised personnel who have carried out maintenance work on items to be credited for Class.
- An LR *Certificate of Operation* of an Approved Planned Maintenance Scheme for Hull Structures.
- Confirmation of the type of planned maintenance software in use.
- Reports will be required to be forwarded to the Scheme Manager on a 3-monthly basis.

14.4.7 **Lloyd's Register Surveyors.** At the Annual Audit held concurrently with the Annual Classification Survey, the hull records and documentation will be examined in sufficient depth by the LR Surveyors to ensure that the scheme has been operated correctly and that structure and coatings/ corrosion prevention systems have functioned satisfactorily since the previous Audit. The records should indicate that all scheduled maintenance has been carried out. Any items not dealt with as per the schedule will be discussed with the authorised personnel.

14.4.8 As part of the Audit the LR Surveyors may carry out a general examination of the hull structural items completed in the previous year. If the Surveyor is not satisfied with any aspect of the scheme's operation he/she may request that items be opened out for inspection.

14.4.9 If deficiencies in the operation of the scheme are identified, either from the maintenance records or from the general condition of the ship, the Surveyors may advise that a further Audit will be required and impose a suitable Condition of Class. In the event of serious deficiencies, a report will be forwarded to the Naval Ship Classification Committee in London recommending that the special arrangements for dealing with hull structural surveys be suspended.

14.4.10 The dates of items to be credited for Class will be aligned to the date of the Annual Audit, regardless of when the survey was carried out by the ship's staff. Any other surveyable items of hull structure not covered by the Scheme will be surveyed and credited in the normal way.

14.4.11 It should be noted that when items that the ship's staff are authorised to survey become due for survey between Annual Audits, they will be shown as 'OVERDUE' on the survey status until the Annual Audit has been held and reported.

14.4.12 Items approved for inspection by the ship's staff, but not inspected by them between Annual Audits according to the approved schedule of inspections, will require to be examined by the LR Surveyor at the time of the Annual Audit.

14.4.13 **Inspection Results and Reporting.** Results of the inspections carried out by authorised ship's staff in accordance with the approved schedule of inspection should be recorded on the report forms provided by LR and transmitted to the Scheme Manager at the required intervals. Where previously agreed with the Scheme Manager, alternative methods of reporting may be accepted.

14.4.14 Should the authorised ship's staff, during the course of their inspections, identify any defect or damage which could invalidate the conditions of class for which a vessel has been assigned, this should be reported to LR without delay. In such cases, an LR Surveyor should be requested to attend the ship to carry out an appropriate survey in accordance with normal practice. All repairs that may be required in order for the ship to maintain class are to be carried out to the satisfaction of an LR Surveyor. When repairs are effected at a port, terminal or location where the services of an LR Surveyor are not available, the repairs are to be surveyed by an LR Surveyor at the earliest opportunity thereafter.

■ *Section 15* Machinery planned maintenance and condition monitoring, MPMS, MCM and RCM

15.1 Introduction

15.1.1 Within the scope of Ch 2,4.5.18 and 4.5.19, an approved Planned Maintenance Scheme (MPMS) and Condition Monitoring (MCM) can be accepted as an integral part of LR's Continuous Survey Machinery (CSM) cycle.

15.1.2 Planned maintenance systems may be based on calendar or running hours calling for items to be opened out for inspection and overhaul at specified periods. Alternatively the machinery may be monitored for condition and performance, whereby items need only be opened out for examination when readings indicate deterioration.

15.1.3 Navies who operate a planned maintenance scheme that meet the LR requirements will benefit from enhanced arrangements for dealing with machinery surveys. The arrangements provide the following advantages:

(a) A more flexible approach to dealing with Classification Surveys of machinery items. The condition as observed and reported by LR approved Marine Engineer Officer will, subject to annual audit, be sufficient to credit the items for survey.

(b) A single system can be operated by the Navy covering maintenance, spare parts supply and survey requirements.

(c) The schemes allow the application of condition monitoring techniques to main and auxiliary items of machinery.

15.1.4 When a Navy decides to apply such arrangements to limit the opening out normally required for survey under CSM then **MPMS, MCM** (including Condition Monitoring) or **RCM** (including Reliability Centred Maintenance) class notations can be assigned where the schemes have been approved by LR.

15.2 Master list items

15.2.1 A list of typical machinery master list items that can be surveyed by authorised personnel and those items that remain to be dealt with by LR Surveyors can be obtained from LR's London Office. It should be noted that LR will continue to inspect, as necessary, where there is a history of mechanical, electrical or control engineering defects in a particular area, either on the ship or on a similar ship.

15.3 The planned maintenance approach

15.3.1 Types of maintenance are defined as:

(a) **Preventive maintenance**. This calls for items to be opened out for inspection and overhaul at specified time periods or after a specified number of running hours in order to keep the machine/equipment/system in a satisfactory operational condition.

(b) **Condition based maintenance**. This is dictated by the performance or physical state of the machine/equipment/system, determined by regular or continuous checks of applicable parameters. Maintenance is only undertaken when conditions have approached or reached the lowest acceptable standard and before breakdown or failure occurs.

(c) **Reliability centred maintenance**. This calls for a structured analysis of a system's capability to perform its functions from design through operation to decommissioning. The primary objective is to ensure the functionality of a system and this is achieved through a planned maintenance strategy determined from the detailed analysis. The strategy may include the use of prevention and condition based maintenance.

15.3.2 The types of maintenance described in 15.3.1 are the foundations of a Machinery Planned Maintenance System acceptable to LR. Many schemes are made up with a combination of the three methods of control. In addition, to deal with unforeseen circumstances, any Machinery Planned Maintenance System must also be able to deal effectively with breakdown or corrective maintenance, i.e. unscheduled maintenance.

15.4 Basic requirements for approval of MPMS, MCM and RCM schemes

15.4.1 To obtain approval of a MPMS, the Navy is required to make a formal request through either a local office of LR or direct to LR in London. The request is to be accompanied by the following information:

(a) A numbered index of the items to be included in the scheme. This index is to include at least all CSM items that appear on the Master List of Surveyable Items. The scheme can also cover many items that are not required for classification. The indexing system is to be such that ready cross-reference to the numbers in the LR Master List of Surveyable items can be made. It is also to indicate those items to be dealt with by preventive maintenance, by condition based maintenance and by reliability centred maintenance.

(b) The maintenance and monitoring methods to be used, the time schedules for each item and limits of acceptance/condition where applicable. Maintenance descriptions are to cover at least the minimum opening out necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A few sample job descriptions will suffice to demonstrate how the system works. Machinery on preventive maintenance must be examined completely for survey purposes at intervals not exceeding six years, although in practice many items will be maintained much more frequently.

(c) A system for reporting to the Navy and recording on board ship and at the Navy's headquarters, details of maintenance carried out, the condition as found and any repairs effected, together with a list of spare parts used. The reporting and recording procedures are to be sufficiently comprehensive to demonstrate that both the Navy and the LR Surveyor can verify correct operation of the planned maintenance system at the time of the survey.

(d) A description of the scheme regarding its application on board ship and the proposed flow of maintenance documents and method of filing same. The application of the scheme may take the form of simple planning charts or the more complex interactive computer based systems. The language of the MPMS is to be English.

15.4.2 Where a Navy has requested approval of a Reliability Centred Maintenance study, the requirements of 15.4.3 to 15.4.5 are to be complied with.

15.4.3 The following information is to be submitted to LR for review.
(a) Hard or soft copy (with operating systems if necessary) of the studies. This is to include, operating context, details of study team, FMECA, algorithm decision sheets, summary of maintenance tasks, summary of 'level of repair analysis', identification of 'critical' spares.
(b) Details of system/equipment covered by the study.
(c) Copy of acceptance letter from equipment manufacturer confirming their review of the study details.

15.4.4 LR will verify by audit that the following items have been complied with:
(a) Study has been undertaken in full compliance of the methodology embodied in an acceptable and applicable standard for RCM.
(b) Study team members have adequate experience both of undertaking RCM studies and the systems/equipment under review.
(c) Study team members have been present during the study for sufficient time (% of total time taken) to properly contribute to the study.
(d) No 'Mandatory Redesign' requirements are outstanding.
(e) Where spares have been identified as 'Critical', they have been properly identified in the management systems on board.
(f) Procedures for collection of condition monitoring information have been established and reporting procedures for submission of this as part of the approved MPMS are clearly documented.
(g) Where Standard Operating Procedures have been identified, that an adequate management system is in place to ensure that they are complied with.
(h) The FMECA is in compliance with an acceptable standard, good marine engineering practice and application of valid reliability data.

15.4.5 A technical audit by LR of individual RCM studies selected by LR will follow the following methodology:
(a) Verification that the study covers the entire function being addressed.
(b) For each individual study (sub function) within a group function, verification that there is a list that includes the individual assets items, including controls, instrumentation and protective/ emergency devices.
(c) Verification that an expected maintenance task list has been drafted, based on typical tasks that would be expected for the relevant item, under any maintenance regime. These would include, but may not be limited too, system performance analysis checks, standard condition monitoring checks (vibration, electrical characteristics, thermography, etc), inspections of items liable to wear or other age related degradation, i.e. fouling, periodic tests of protective devices, operation of reversionary modes of operation, etc.
(d) Confirm that the standard tasks have been identified for each sub function.
(e) Review the study for justification for items or systems with no scheduled maintenance for tasks not identified.
(f) Review any inconsistencies in periodicity for tasks included in maintenance schedule.
(g) Carry out a review of RCM logic applied for one sub function. If the review is acceptable and in accordance with the standard for RCM, others will not be fully reviewed. If considered unacceptable, a review of another will be carried out for confirmation. If second also unacceptable, LR will require a complete review of all other sub functions for acceptance.
(h) Review LR Master List Surveyable items to verify that all Class items have a maintenance programme associated with credit as part of RCM.

15.4.6 As an alternative to LR carrying out post study audits required by 15.4.4 and 15.4.5, LR can, if requested provide direct input and advice to the study team(s) on either full or part time basis to supplement the technical/survey requirement input. If this is undertaken, the scope of the audit will be reduced accordingly.

15.4.7 Where machinery items are maintained on a condition basis the following additional information is required to be submitted:
(a) A description of the applicable monitoring techniques and monitoring equipment to be used.
(b) A statement as to the acceptable limits of deteriorated condition. These should be derived from the manufacturer's recommendations, applicable severity criteria as defined in recognised Standards, or the Navy's required limits when these are more severe. Rotating machinery on condition based maintenance may be accepted for survey on the basis of the monitored readings without opening out if the condition is shown to be good.

15.4.8 If the planned maintenance scheme is considered to be acceptable to LR a 'Certificate for Operation of an Approved Planned Maintenance Scheme' will be issued. The Certificate is to be retained on board the subject ship for the information of the Commanding Officer, Marine Engineer Officer and LR's Surveyors.

15.4.9 The Marine Engineer Officer operating the Scheme on a ship must hold a valid LR Certificate of Authorisation.

15.5 Conditions of operation

15.5.1 It is a condition of the Scheme that the Navy arranges for LR's Surveyors to carry out an Annual audit of the machinery maintenance and monitoring records. Annual audits are to be held within three months before or after the due date and it is recommended that they are harmonised with the ship's Annual Survey.

15.5.2 Marine Engineer Officers may carry out surveys of all the machinery items for which they are authorised, at sea or in port, whichever is the most convenient. The following machinery items remain to be dealt with by an LR Surveyor, unless special arrangements have been agreed with the Navy:

- Machinery damage, repairs and alterations, *see* 15.6.
- Gas turbines for propulsion and electrical supplies.
- Oil engines for propulsion and electrical supplies.
- Steam turbines and boilers for propulsion and electrical supplies.
- Control, alarm and safety devices associated with the above main and auxiliary machinery.
- Reduction/increase gearing, flexible couplings and clutches.
- Holding down bolts and chocks.
- Steam pipes and valves on ships with steam turbine installations.
- Air receivers and other pressure vessels.
- Starting air pipes.
- Steering machinery.
- Pumping arrangements for bilge and dewatering systems.
- Electrical equipment other than auxiliary motors.
- Screwshafts, stern bearings and propellers.
- Sea connections.
- Machinery controls and controls associated with Class Notations, e.g. UMS, CCS, ICC, IP and DP.
- Engine Trial.
- First start arrangement trial.

15.5.3 The confirmatory survey carried out at the time of the annual audit by LR's Surveyor will comprise of checks of the condition monitoring records and, if considered necessary, an examination of selected main and auxiliary machinery under working conditions.

15.6 Breakdown or corrective maintenance

15.6.1 LR is required to be notified when a breakdown or defect occurs and has a major effect that affects the Provisions of Classification and repairs are necessary. A major effect is an effect that produces:

(a) a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself should not be outside the capability of a competent crew provided that another major effect does not occur at the same time; or

(b) significant degradation in the operational capability of the ship; or

(c) significant modification of the permissible operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

15.6.2 In discussion with the Navy and the Marine Engineer Officer, LR will advise what repairs and/or renewals are necessary for classification purposes, with the issue of an Interim Certificate of Class.

15.6.3 The required repair and time scale for completion will be the subject of discussion and agreement with LR and the Navy. It is the responsibility of the Navy to decide whether the ship's mission/operational tasking is more important than completing the repairs within the agreed time. It is accepted that such circumstances are occasionally inevitable, and LR would provide advice on the interim measures that could be introduced until such times as the required repairs are carried out and the implications on a ship's operating capability of delays in affecting repairs.

15.7 Annual audit and survey

15.7.1 At the annual audit the Marine Engineer Officer is required to make available the maintenance and monitoring records. These records may be in a hard or soft format and should include:

(a) Appropriate records of machinery or equipment surveyed under the supervision of the Marine Engineer Officer that are listed in the Master List of Surveyable Items. These statements should give details of repairs carried out and spare parts used.

(b) Written details of any breakdown or malfunction of essential machinery. Such details should include the main cause of failure.

(c) LR Certificate(s) of Authorisation for the Marine Engineer Officer(s) responsible for surveys during the period.

These records will be examined in sufficient depth by the LR Surveyors to ensure that the scheme has been correctly operated and that the machinery has functioned satisfactorily since the previous survey. The records should indicate that all scheduled maintenance has been carried out. Any items not dealt with as per schedule will be discussed with the Marine Engineer Officer.

15.7.2 Where condition monitoring of main or auxiliary machinery is incorporated in the PMS the LR Surveyor will examine the records to verify that vibration levels, performance criteria, etc., are within the approved specified limits. The LR Surveyor may require confirmatory readings on available running machinery to be taken for comparison with the ship's records.

15.7.3 As part of the audit, LR Surveyors carry out a general examination of the machinery. As far as is practicable machinery to be credited for survey will be examined under working conditions. If the LR Surveyor is not satisfied with the condition as found he might require to have any items opened out for inspection.

15.7.4 The dates of items to be credited for Class will be aligned to the date of the confirmatory survey regardless of when the Marine Engineer Officer carried out his survey. Any other surveyable items of machinery not covered by the Scheme will be surveyed and credited in the normal way.

15.7.5 For items which the Marine Engineer Officer is authorized to survey and become due for survey between Annual Audits these will be shown as 'OVERDUE' on the survey status until the Annual Audit has been held and reported.

15.7.6 In the event of the Surveyor not being satisfied that the planned maintenance scheme is being correctly followed, either from the maintenance records or from the general condition of the machinery, a report will be forwarded to LR recommending that the special arrangements for dealing with machinery surveys be suspended.

■ *Section 16* Classification of ships not built under LR survey

16.1 General

16.1.1 When classification is desired for a ship not built under the supervision of LR's Surveyors, application should be made in writing.

16.1.2 Periodical Surveys of such ships, when classed, are subsequently to be held as in the case of ships built under survey.

16.1.3 Where classification is desired for a ship which has not been designed, constructed and maintained to appropriate standards recognised by the Naval Authority, special consideration will be given to the requirements of this Section.

16.1.4 Where classification is desired for a ship which is classed by another recognised Society, special consideration will be given to the requirements of this Section.

16.2 Hull and equipment

16.2.1 Plans showing the main scantlings, corrosion margins and arrangements of the actual ship together with any proposed alterations are to be submitted. Documents demonstrating compliance with appropriate standards recognised by the Naval Authority are to be submitted. In the absence of such documentation, an appraisal may be required to the satisfaction of LR. These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

16.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite ships will be specially considered.

16.2.3 The full requirements of Sections 5 and 6 are to be carried out as applicable. Ships of recent construction will receive special consideration.

16.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of a steel ship, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted.

16.2.5 When the full survey requirements indicated in 16.2.3 and 16.2.4 cannot be completed at one time, LR may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merit of each particular case, which should be submitted for consideration.

16.3 Machinery

16.3.1 To facilitate the survey, plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings are to be furnished:

General piping system arrangements, including air and sounding pipes (Builder's plan).
Bilge, dewatering, ballast and oil fuel piping arrangements including the capacities of the pumps on bilge service.
Arrangement and dimensions of main steam pipes.
Arrangement of oil fuel pipes and fittings at settling and service tanks.
Arrangement of oil fuel piping in connection with oil burning installations.
Oil fuel overflow systems, where these are fitted.
Arrangement of boiler feed systems.
Oil fuel settling, service and other oil fuel tanks not forming part of the ship's structure.
Boilers, superheaters and economizers.
Air receivers.
Crank, thrust, intermediate and screw shafting.
Clutch and reversing gear with methods of control.
Reduction gearing.
Propeller (including spare propeller if supplied)
Electrical circuits, as listed in Vol 2, Pt 10, Ch 1,1.2.2, 1.2.3 and 1.2.4.
Arrangement of compressed air systems for main and auxiliary services.
Arrangement of lubricating oil, hydraulic oil, thermal oil and other systems containing flammable liquids.
Arrangements of cooling water systems for main and auxiliary services.
Steering gear system and piping arrangements together with manufacturer, model and rating information.
Aircraft/helicopter and vehicle fuel storage and distribution systems.
Chilled water systems.
High pressure sea water systems.
Propulsion engine details including manufacturer, model and rating information.
Electrical generator engine details including manufacturer, model and rating information.
For **UMS** notation the following plans are to be submitted for appraisal:

- Fire alarm system.
- Instrumentation list.
- Plans for systematic maintenance and function testing.
- Test schedule.

Where an Ice Class notation is required the following plans are to be submitted for appraisal:

- Main propulsion line shafting.
- Reduction gears.
- Propeller.
- Details of any clutch system in the propulsion line.

16.3.2 Plans additional to those detailed in 16.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

16.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

16.3.4 For new ships and ships which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older ships the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, LR may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

16.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

16.3.6 The screwshaft is to be drawn and examined.

16.3.7 The steam pipes are to be examined and tested as required by Section 12.

16.3.8 The bilge, dewatering, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

16.3.9 Oil burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

16.3.10 The electrical equipment is to be examined as required at Complete Surveys.

16.3.11 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor’s satisfaction.

16.3.12 Relevant reports are to be prepared by the Surveyors.

■ *Section 17*
Classification of ships built under survey to LR Classification Rules and Regulations other than LR Naval Ship Rules and Regulations

17.1 General

17.1.1 When classification is desired for an existing ship built under the supervision of LR's Surveyors to Classification Rules and Regulations other than LR Naval Ship Rules and Regulations, application should be made in writing.

17.1.2 Periodical Surveys of such ships, when classed to the LR Naval Ship Rules and Regulations are subsequently to be held as in the case of ships built under survey to the Naval Ship Rules and Regulations. All features of the extant survey regime for hull and machinery are to be included in the Survey scheme under the Naval Ship Rules and Regulations.

17.2 Hull and equipment

17.2.1 Plans showing the features not covered by merchant classification are to be submitted. These may include the following which should be addressed for strength and, where appropriate, stiffness aspects:

- Masts.
- Weapon system seats.
- RAS seats, landing areas.
- Aircraft landing guides.
- Towing points.
- Military loads.

If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

17.2.2 Suitable documentation should be presented to demonstrate that the following aspects are addressed by the appropriate Naval Authority:

- Stability.
- Magazine safety.
- Lifts, ramps, shell doors.
- Fire safety.

17.2.3 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements of additional features covered by the Naval Ship Rules. For this purpose, and also in order to ascertain the amount of any deterioration of a steel ship, parts of the structure may need to be gauged as necessary.

17.2.4 When the full survey requirements indicated in 7.2.4 cannot be completed at one time, LR may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merit of each particular case, which should be submitted for consideration.

17.3 Machinery

17.3.1 To facilitate the survey of systems not covered by the other Classification Rules with which the ship is classed, the following details are to be furnished:

- Aircraft/helicopter and vehicle fuel storage and distribution systems.
- Chilled water systems.
- High pressure sea water systems.
- High and low pressure compressed air systems.
- RAS arrangements.

17.3.2 Details additional to those detailed in 16.3.1 are not to be submitted unless the machinery or installation is of a novel or special character affecting classification.

17.3.3 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor's satisfaction.

17.3.4 Relevant reports are to be prepared by the Surveyors.

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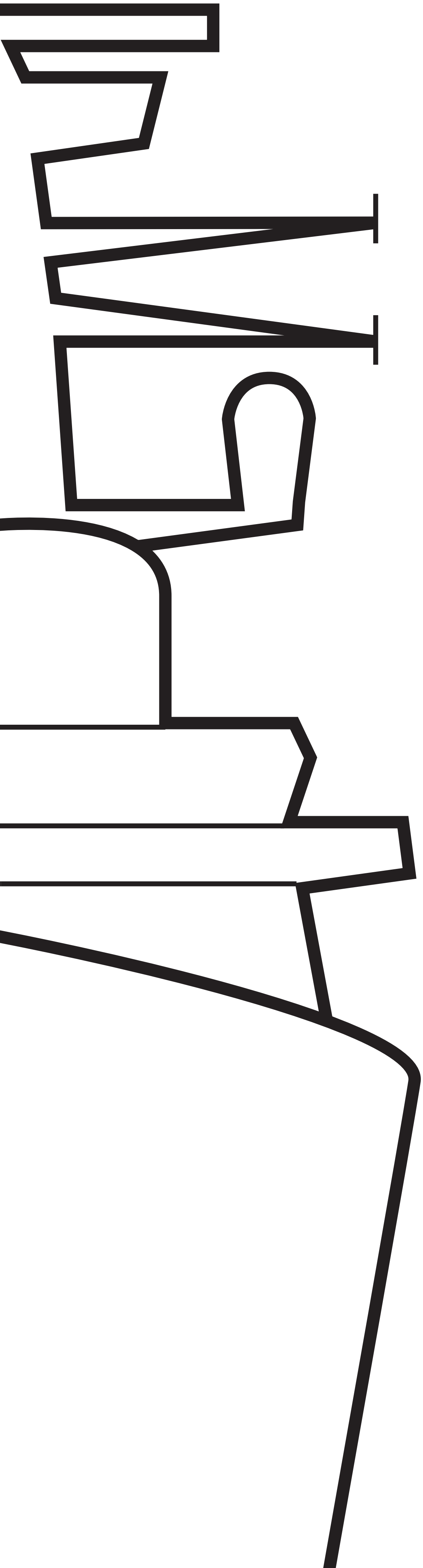


Rules and Regulations for the Classification of Naval Ships

Volume 1 *Parts 3–6*

Ship structures

January 2005

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda. A dot-dash line indicates changes necessitated by International Conventions, Code of Practice or IACS Unified Requirements.

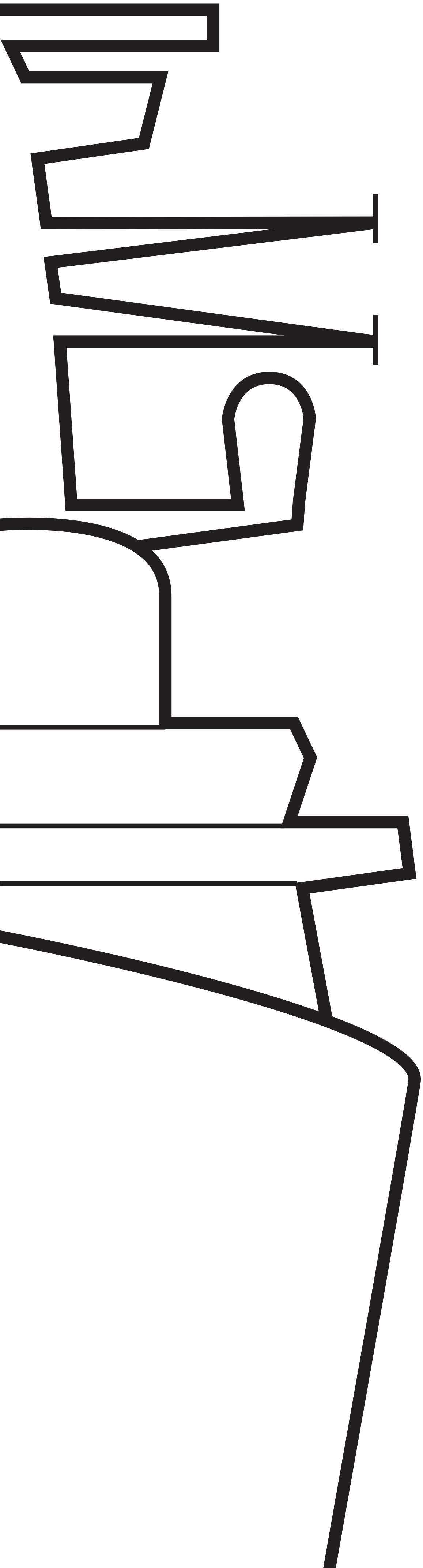
Rules programs

LR has developed windows based Rules Calculation Software which evaluates Rule Requirements for Special Service Crafts' structures. For details of this software please contact Lloyd’s Register.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to Lloyd’s Register’s own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2005



Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 3*

Design principles and constructional arrangements

January 2005

Lloyd's Register

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Section

■ *Section 1* Rules application

1.1 General

1.1.1 The Rules apply in general to ships of normal form, proportions and speed. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in the construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, or for special or restricted service, or purposes not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly handled. The Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.8, trim, vibration (other than local panel) and docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

1.5 Interpretation

1.5.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to a 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal. Similarly, where there is any doubt regarding the interpretation of the Owners' requirements it is the designers' responsibility to obtain clarification from the Owners prior to the submission of plans.

1.5.2 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules. Whilst they will not be mandatory for naval ships they may be adopted as identified by the Naval Authority.

1.6 Aesthetics

1.6.1 LR is not concerned with the general arrangement, layout and appearance of the ship; the responsibility for such matters remains with the Builders and/or Designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules, LR Survey Procedures or equivalent are to be complied with.

1.7 Constructional configuration

1.7.1 The Rules provide for a basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of deck openings, and tanks.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for ships having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposition of output rests with the Designer.

■ *Section 3* Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses, factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a Naval Authority may be accepted as equivalent to the requirements of this Part of the Rules.

■ *Section 4* Information required

4.1 Submission of plans and data

4.1.1 Plans and data required to be submitted are indicated in Pt 6, Ch 1,2.2.

4.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

4.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

4.2 Standard designs

4.2.1 Where a ship is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

4.2.2 Where the ship is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

4.2.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

4.3 Plans and data to be supplied to the ship

4.3.1 A copy of the final Loading Manual or stability information book, (where applicable) when approved, and details of the loadings applicable to approved decks, are to be placed on board the ship.

4.3.2 Copies of all main scantling plans are to be readily available on board ship for the purposes of repairs, identifying materials and condition assessment.

4.3.3 Details of any corrosion control system fitted are to be placed on board the ship.

4.3.4 Where in-water surveys are required, approved plans and information covering the items detailed in Pt 6, Ch 1,2.2 are to be placed on board.

■ *Section 5* Definitions

5.1 General

5.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

5.2 Principal particulars

5.2.1 Length waterline, L_{WL}, is the distance, in metres, measured on a waterline at the design draught from the fore side of the stem to the after side of the stern or transom as shown in Fig. 1.5.1.

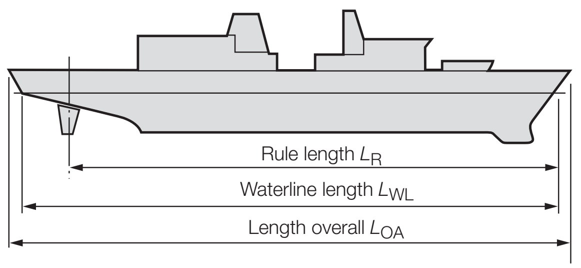


Fig. 1.5.1 Lengths

5.2.2 Rule length, L_R, is the distance, in metres, on a waterline at the design draught from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on a waterline at the design draught. In vessels without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on a waterline at the design draught. In vessels with unusual stem or stern arrangements, the Rule length will be specially considered.

5.2.3 All references to longitudinal locations in the Rules are to be taken as forward of the aft end of L_R unless otherwise stated, e.g. 0,75L_R is 75 per cent of L_R forward of the aft end of L_R.

5.2.4 Length between perpendiculars, L_{PP}, in metres is the distance, in metres, on the waterline at the design draught from the forward to the after perpendicular.

5.2.5 The forward perpendicular, F.P., is the perpendicular at the intersection of the waterline at the design draught with the fore side of the stem.

5.2.6 The after perpendicular, A.P., is the perpendicular at the intersection of the waterline at the design draught with the after side of the rudder post or to the centre of the rudder stock for vessels without a rudder post or to the intersection with the transom profile on the centreline.

5.2.7 Length overall, L_{OA} , is the distance, in metres, measured parallel to the deep load waterline from the fore side of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections as shown in Fig. 1.5.1.

5.2.8 Waterline breadth, B_{WL}, is generally the greatest moulded breadth, in metres, measured at the design draught, as shown in Fig. 1.5.2.

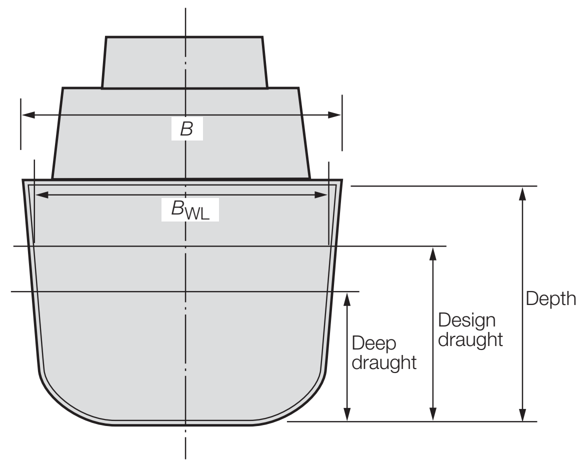


Fig. 1.5.2 Transverse dimensions

5.2.9 Breadth, *B*, is generally the greatest moulded breadth, in metres, throughout the depth of the ship or as defined in appropriate chapters. For vessels of unusual cross section the breadth will be specially considered.

5.2.10 Depth, *D*, is measured, in metres, at amidships, from top of keel plate to the moulded deck line at side on the uppermost continuous deck, or as defined in appropriate chapters or standards. When a rounded gunwale is arranged, the depth *D* is to be measured to the continuation of the moulded deck line at side.

5.2.11 Draught, *T*, is the design draught, in metres, measured from moulded baseline.

5.2.12 Block coefficient, C_b , is the block coefficient at draught *T* corresponding to a waterline at the design draught, based on Rule length L_R and breadth B_{WL}, as follows:

$$C_b = \frac{\text{moulded displacement } (m^3) \text{ at draught } T}{L_R\, B_{WL}\, T}$$

5.2.13 Design draught may be determined from the waterline when the vessel is in a deep condition plus any specified margins. In special circumstances, the operation of the vessel or the Owner's specification may require that a higher waterline be used.

5.2.14 Deep draught is measured at a displacement such that the ship is in all respects complete, and is fully loaded with full complement, stores, fuel, water and payload.

5.2.15 Payload is the equipment and stores that are carried by the vessel for the purposes of fulfilling its operational requirements.

5.3 Margins

5.3.1 Design margin is an allowance for uncertainties used in the estimation of weight for design purposes.

5.3.2 Build margin is an allowance for unforeseen changes that may need to be made by the builder of the vessel.

5.3.3 Admiralty board margin is an allowance to cater for modifications made by the Owner to the vessel or equipment during the design and build stages.

5.3.4 Growth margin is an allowance for future controlled and uncontrolled weight growth during the life of the ship.

5.3.5 In the absence of any specific requirements, the sum of the margins is be taken as 15 per cent of the displacement at the deep draught.

5.4 Decks

5.4.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective. Where the upper deck is stepped, as in the case of vessels with a quarter deck, the strength deck is stepped. (*See* Pt 6, Ch 4,1).

5.4.2 The weather deck is generally the lowest continuous deck exposed to sea and weather loads. It is to be defined at the early stages of design in conjunction with LR and the Builder.

5.4.3 Other decks that are exposed to sea loads are to be assessed in accordance with the requirements for weather decks.

5.4.4 The damage control deck is the lowest deck on which continuous fore and aft access is provided to aid communications and recovery following damage. It is normally above the lowest vertical limit of watertight integrity the exact location being determined by the relevant sub-division and watertight integrity standard.

5.5 Co-ordinate system

5.5.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.5.3, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

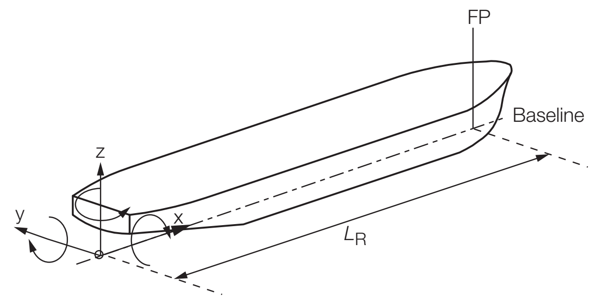


Fig. 1.5.3 NSR Co-ordinate system

5.6 Superstructure

5.6.1 For the purposes of strength assessment a superstructure is defined as a decked structure on the strength deck, extending from side to side of the vessel, or with its side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

5.7 Deckhouse

5.7.1 A deckhouse is in general defined as a decked structure on or above the strength deck with its side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

5.8 Weathertight

5.8.1 A boundary or closing appliance is considered weathertight if it is capable of preventing the passage of water into the ship in any sea conditions.

5.9 Watertight

5.9.1 A boundary or closing appliance is considered watertight if it is capable of preventing the passage of water in either direction under a head of water for which the surrounding structure is designed.

5.10 Terminology

5.10.1 Fig. 1.5.4 shows the general terminology adopted for structural items for a transversely and longitudinally framed ship.

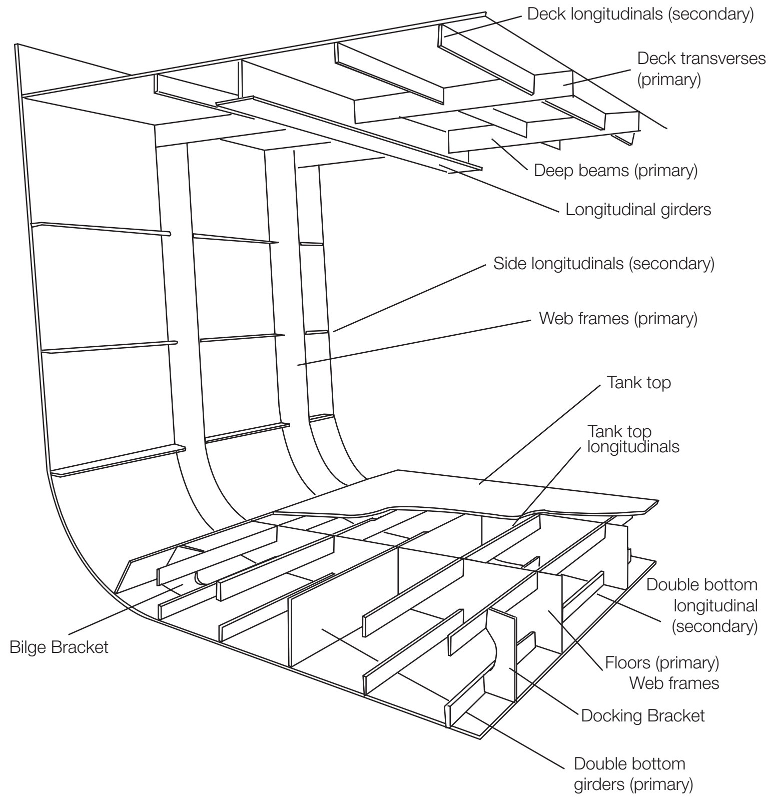


Fig. 1.5.4a Longitudinal framing system

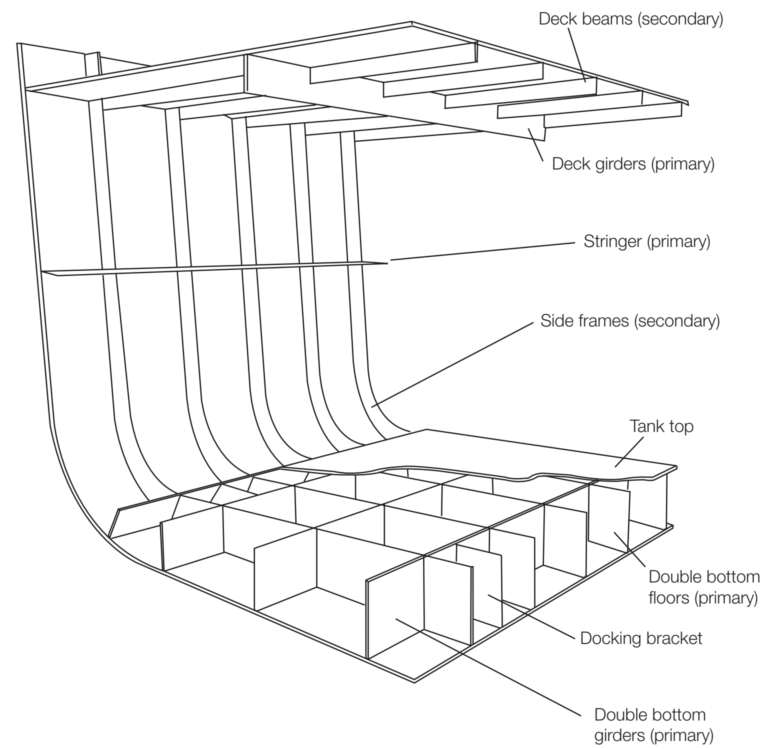


Fig. 1.5.4b Transverse framing system

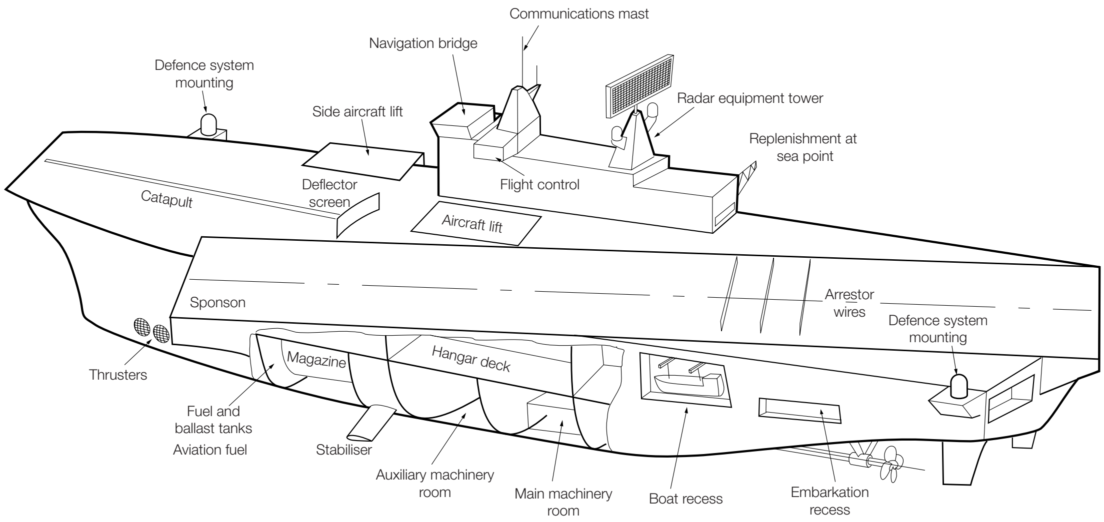


Fig. 1.5.5a NS1 Conventional aircraft carrier

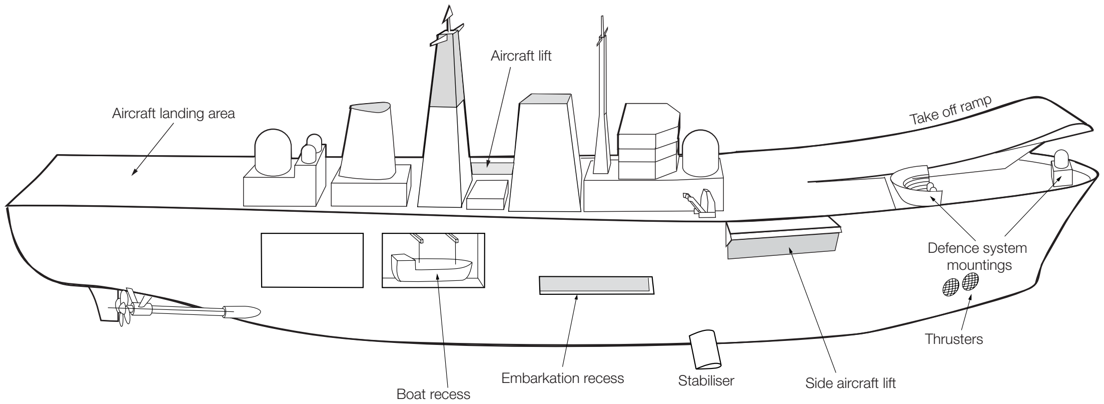


Fig. 1.5.5b NS1 Short take off aircraft carrier

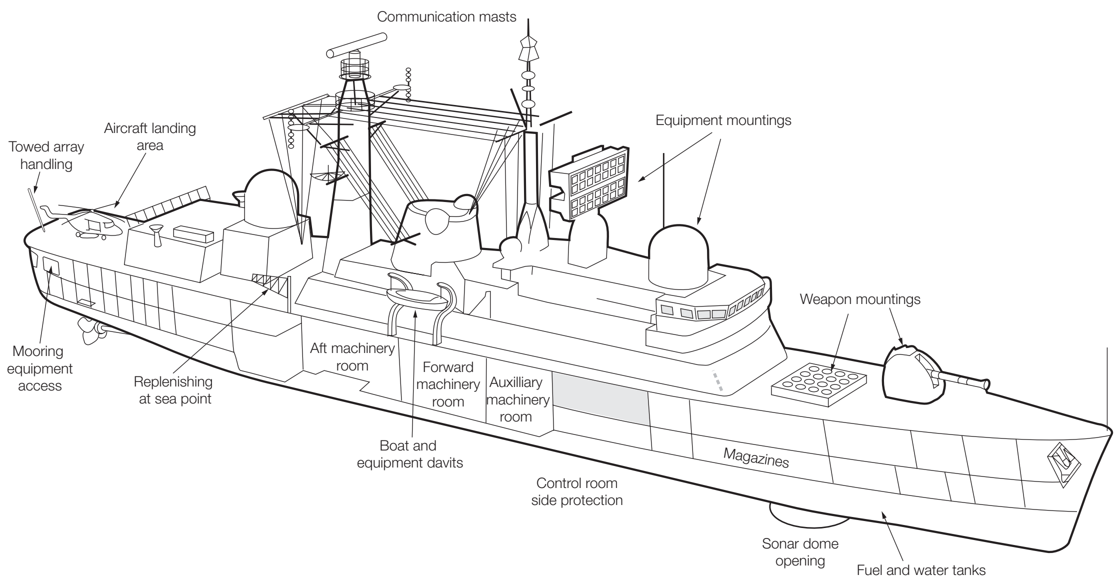


Fig. 1.5.5c NS2 Frigate/Destroyer

5.10.2 Fig. 1.5.5 shows the general configuration of Naval ships of the NS1 and NS2 types. Various features are pointed out and are dealt with by the relevant section of the Rules.

5.11 Extent of watertight subdivision

5.11.1 The minimum extent of watertight subdivision (internal), and integrity (internal and external), shall be such that it satisfies the requirements of the Navy. The standard of watertight subdivision and integrity shall be defined by the Navy or its nominated Naval Authority.

5.11.2 The minimum extent of watertight subdivision may be defined by a combination of decks, side shell and bulkheads or by a single deck.

5.11.3 Weathertight and watertight fittings and closing appliances are to be fitted in accordance with the requirements of the boundary on which they are placed.

5.11.4 For the calculation of watertight structural scantlings the pressure head is to be taken from the vertical limits of weathertightness determined by either intact or damage stability considerations determined by Ch 2,1.3 or the Naval Authority, *see* Pt 5, Ch 3,5.5.

5.12 Critical compartments

5.12.1 A critical compartment is one which, at battle stations, contains equipment or personnel without whom functions critical to combat survivability would be lost. These functions include the ability to fight, manoeuvre or communicate.

5.12.2 Critical compartments are typically the chart room, operations room, conning position, ship's control room and main communications office. Other compartments may be considered critical depending on ship's layout and design. The need for protecting critical compartments can be reduced by avoiding single point failure nodes and by concentrating and protecting those which cannot be avoided. A vulnerability analysis can be used to identify vulnerable critical compartments and the essential pieces of equipment or systems that are required to be protected (*see* 2.2).

5.12.3 Critical pipe and cable runs are routes in which the connections for survivability critical components run. They can cover individual routes or concentrated areas. An example is a run containing wave guides and signal cables for all the above water sensors on the mast.

5.13 Units system

5.13.1 Unless otherwise stated, the variables used in the Rules are expressed in the following units.

5.13.2 **General**

Distances	m
Primary spacings	m
Secondary spacings	mm

5.13.3 **Hull girder properties**

Dimensions	m
Area	m^2
Section modulus	m^3
Inertia	m^4
Area-moment	m^3

5.13.4 **Stiffeners**

Area	cm^2
Dimensions	mm
Inertia	cm^4
Section modulus	cm^3
Length/length effective	m

5.13.5 **Plating**

Breadth	mm
Length	m
Thickness	mm

5.13.6 **Loads**

Pressures	kN/m^2
Loads	kN
Bending moment	kN-m
Shear force	kN

5.13.7 **Other items**

Yield strength	N/mm^2
Stress	N/mm^2
Deflections	mm
Modulus of Elasticity	N/mm^2

■ *Section 6* Building tolerances and associated repairs

6.1 Overview

6.1.1 The general tolerances for new building and subsequent repairs are to be in accordance with the requirements of the Naval Ship Survey Procedures Manual.

6.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/Builders and the Surveyor and acceptable Standards agreed subject to the requirements of 6.1.1 or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Equipment supporting structure or underwater plate near acoustic equipment.
(d) Aesthetically pleasing.

6.1.3 The requirements of these Rules are primarily concerned with ensuring items (a) and (b). The equipment manufacturer will be able to give advice on the maximum noise or misalignment that can be tolerated from item (c). Aesthetics, item (d) are at the discretion of the Owner.

■ *Section 7* Inspection and testing

7.1 Overview

7.1.1 The general requirements for testing and inspection of structural items are to be in accordance with the requirements of the Vol 1, Pt 6, Ch 6,6 and LR's *Naval Survey Guidance for Steel Ships*.

7.1.2 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and testing of all components during each stage of prefabrication and construction.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in the design of naval ships. Principles for subdivision and for maintaining watertight integrity are also covered.

1.1.2 Where additional requirements relating to particular ship types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

1.2 Definitions

1.2.1 The Down flooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.2.2 The minimum required angle of down flooding, θ_{df}, is to be taken as 40° except when a higher minimum angle is required by the stability and subdivision standard specified by the Naval Authority, *see* Pt 1, Ch 2,1.1.9

1.3 Watertight and weathertight integrity

1.3.1 The extents of the external and internal watertight and weathertight integrity are defined by the intact and damage stability requirements, *see* Pt 1, Ch 2,1.1.9. From these extents, the design pressure heads for bulkheads and other boundaries can be derived as well as the closing arrangement requirements for openings. Weathertight and watertight integrity are defined in Ch 1,5 and *see* Ch 4 for the requirements for closing arrangements.

1.3.2 **Intact stability**

1.3.2.1 Intact stability calculations to satisfy the applicable criteria may be based on the buoyancy of the main hull, together with any superstructures that have watertight and weathertight boundaries, *see* Fig. 2.1.1(a) and Fig. 2.1.2(a).

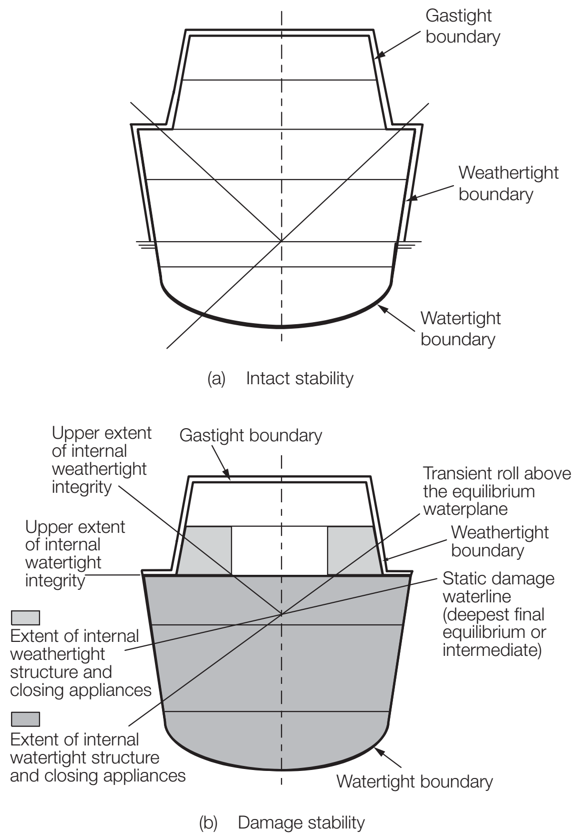


Fig. 2.1.1 International standards

1.3.2.2 Doors, hatches, ventilators, windows, sidelights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.3.2.3 If the angle of down flooding is less than θ_{df}, *see* 1.2.2, with the ship at its design draught, it is necessary to establish whether there is sufficient area under the righting lever curve up to the angle of down flooding. If there is insufficient area, then the opening which is causing down flooding to occur is to be provided with a weathertight closing appliance, or be repositioned.

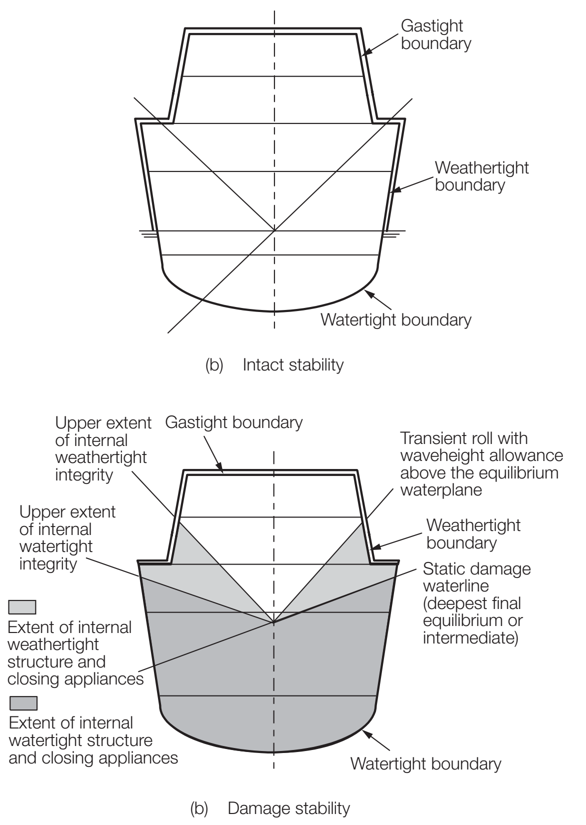


Fig. 2.1.2 Commonly used naval standard

1.3.3 **Damage stability**

1.3.3.1 Typically there are two approaches to defining the limits of watertight and weathertight integrity:

(a) One where the watertight integrity is defined by the bulkhead or freeboard deck, in accordance with normal SOLAS requirements.

(b) The other is based on watertight integrity up to a damaged stability draft and heel envelope, the latter is commonly used by Navies.

These two approaches are illustrated in Figs 2.1.1(b) and 2.1.2(b) respectively.

1.3.3.2 Fig 2.1.1(b) represents the SOLAS style requirements.

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight, in order to prevent ingress of water into the enclosed volume considered buoyant in the stability calculations and prevent downflooding.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gas-tight for NBC protection.
- Below the limit of watertight integrity defined by the top of the watertight bulkhead, the bulkhead is to be designed as watertight.
- Below the limit of weathertight integrity defined by the transient roll angle and above the limit of watertight integrity the internal structure is to be designed to prevent progressive flooding of water into other compartments.

1.3.3.3 Fig. 2.1.2 represents a standard based on damaged stability draft and heel envelope approach commonly used by Navies.

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gas-tight for NBC protection.
- Below the limit of watertight integrity defined by the locii of static damage waterlines the watertight bulkheads are to be designed as watertight.
- Below the limit of weathertight integrity defined by the transient roll angle and above the limit of watertight integrity the internal structure is to be weathertight in order to prevent progressive flooding of water into other compartments.

1.3.3.4 In the absence of specific information on the vertical limit of watertight integrity, the upper extent of the watertight boundary may be assumed with the apex of the triangle on the damage control deck nominated by the Naval Authority at the location under consideration, *see* Fig. 2.1.2 and Pt 3, Ch 1,5.4.4.

1.4 Structural redundancy

1.4.1 The role and duty of a naval ship dictates that a certain degree of structural redundancy should be incorporated in the design. It is recommended that, as a minimum standard, a basic level of structural redundancy is included where practicable. This is normally achieved by considering likely damage scenarios, identifying the effects on structure, assessing the new loads and ensuring that the remaining structure will be satisfactory.

1.4.2 These Rules will not automatically ensure that a ship has structural redundancy. It is the responsibility of the designer to consider and design for the possible loads on a structure from damage scenarios. The **RSA** notation can be used to define residual strength requirements.

1.4.3 At a very basic level structural redundancy can be achieved by considering the removal of appropriate items of structure and re-evaluating the strength of remaining members using the loads presented in these Rules. Alternatively, the overall structural redundancy can be formally assessed and a notation assigned using the residual strength analysis detailed in 1.5.

1.5 Residual Strength Assessment, RSA

1.5.1 The design of a naval ship necessitates the reliable evaluation of its structural vulnerability to ensure the existence of adequate residual strength in the event of structural damage following a contact/collision incident or as a result of wartime activities. This strength assessment is additional to that required to cope with the design bending moments derived from environmental sea-state loading. The **RSA** notation within the Rules may be used to formally assess the overall structural redundancy.

1.5.2 The Owner may specify that a residual strength assessment is not required. In this case, the residual strength notation and all other notations which require the residual strength notation will not be assigned.

1.5.3 The capability to survive is to be judged on the residual structural strength after damage being able to meet specified global strength requirements and also local strength requirements in the event of damage leading to flooding, *see* Pt 6, Ch 4,4.

1.5.4 A residual strength assessment performed as defined in the Rules, assumes that a ship can remain operational for a limited period of time in reduced sea states, *see* Pt 6, Ch 4,1.2. Where a Naval Authority wishes to maintain a high operational capability following damage, special consideration will need to be given and revised criteria will be set.

1.5.5 The Owner may specify an alternative mission statement, in which case the requirements of the residual strength assessment procedure are to satisfy the Owner's definition.

1.5.6 The residual strength assessment as defined in the Rules considers three main definitions of damage:

- Peacetime damage extents, *see* Pt 6, Ch 4,2.
- Military threats, *see* Pt 4, Ch 2,7.
- As defined by the Owner.

1.5.7 The environmental parameters for the residual strength assessment procedure are given in Pt 5, Ch 2. The local and global loads for use in the **RSA** assessment procedure are given in Pt 5, Ch 3,5 and Pt 5, Ch 4,5 respectively.

1.5.8 **RSA** notation assessment levels are given in Pt 4, Ch 2,7. The acceptance criteria and procedures to be adopted for the application of the residual strength notation are given in Pt 6, Ch 4,4. *See also* Pt 1, Ch 2,3.6.9.

1.5.9 Further guidance for undertaking residual strength analysis for the determination of a residual strength notation is given in LR's Naval Ship Guidance Notes.

■ *Section 2*
Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the ship will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.1.2 For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load. Alternative methods will be considered.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, payload, ballast, fuel and other operational loads. However, the Rules assume that the nature and stowage of the payload, ballast, etc., are such as to avoid excessive structural stresses, and deformation.

2.2.2 The design loads and pressures given in Part 5 are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the ship are not impaired.

2.2.4 Static loads are based on standard conditions defined in Part 5, or determined from loading conditions submitted by the Builder.

2.2.5 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.2.6 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave loading conditions.

2.2.7 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed scenarios, etc., of the ship.

2.2.8 Structure in way of Replenishment at Sea, RAS, positions, cranes, heavy lift route points, weapon handling, etc., are to be designed in accordance with Pt 4, Ch 1. The equipment is to be designed in accordance with the requirements of the Naval Authority, *see* Vol 1, Pt 1, Ch 2,1.1.

2.2.9 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, bollards, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.3 Definitions and structural terms

2.3.1 For the purpose of clarifying the nomenclature of items of structure referred to throughout the Rules, the following definitions are given:

- Secondary members are stiffeners supporting shell, deck or bulkhead plating, e.g. side/bottom/deck longitudinals, frames and beams, and transverse/longitudinal bulkhead stiffeners.
- Primary members are those members supporting secondary members and will be the predominant members in grillage systems, e.g:
  - Bottom structure – floors, bottom and inner bottom transverse and girders.
  - Deck structure – deck transverses and girders.
  - Side structure – side transverses and side stringers.
  - Bulkheads – vertical webs and bulkhead stringers.

Deep web frames are members supporting primary members between bulkheads or decks, where additional support is necessary.

2.3.2 The fore end region structure is considered to include all structure forward of $0{,}7L_R$.

2.3.3 The aft end region structure is considered to include all structure aft of $0{,}3L_R$.

■ *Section 3*
Main hull structure

3.1 General

3.1.1 The Rules are formulated to provide for scantling derivation for designs comprising the following structural framing systems. Details of the requirements are given in Pt 6, Ch 2.

(a) Primary/secondary stiffener systems - where, due to the relative differences in stiffness of the members, the secondary members are considered to act independent of, and are supported by, the primary members.

(b) Grillage systems - where the relative stiffness of the orthogonal stiffening is similar and work together to support the applied loads. The grillage system is in turn supported by major structural members such as bulkheads or decks.

3.1.2 For practical reasons of fabrication and continuity of structure, orthogonal systems using members of the same depth should not be employed. A minimum web depth difference of 40 mm is generally to be used to allow for the passage through the web at the intersections.

3.1.3 It is recognised that there will be a reduction in transverse ‘racking’ strength in association with the grillage stiffening system where the predominantly stiffer transverse web of the primary/secondary system is missing. In large areas of grillage systems the ‘racking’ strength, therefore, will be specially considered.

3.1.4 For NS1 and NS2 ships, longitudinal framing, in general, is to be adopted in the bottom shell, decks and inner bottom, with transverse or longitudinal framing at the side shell and longitudinal bulkheads. In NS3 ships, transverse or longitudinal framing may be universally adopted.

3.1.5 The adopted framing system whether longitudinal or transverse is required to be continuous. Where it is impracticable to comply with these requirements or where it is proposed to terminate the framing structure in way of other primary members such as the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. Brackets are in general to have soft toes and to terminate on structure that is capable of supporting the transmitted bending moment and forces.

3.1.6 The arrangement of the connection between any stiffener and bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

3.1.7 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

3.1.8 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment and continuity of strength.

3.1.9 The fitting of pillar bulkheads is preferable to pillars. The fitting of pillars is to be avoided in hangar and vehicle decks and where connected to the inner bottom. Where enhanced shock and blast requirements are specified, only pillar bulkheads may be fitted. When fitted, pillars and pillar bulkheads are to be in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

3.1.10 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

3.1.11 The corners of large openings in the shell and decks from $0{,}25L_R$ to $0{,}75L_R$ are to be elliptical, parabolic or circular. Where predominantly undirectional stress fields are anticipated, elliptical or parabolic corners are recommended. Where biaxial or torsional stress fields are expected, circular corners are recommended.

3.1.12 Where elliptical corners are arranged the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than 2 to 1 nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 2.3.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 2.3.1. An increase in plate thickness will not generally be required.

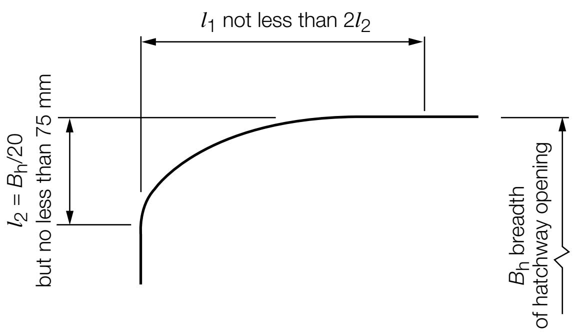


Fig. 2.3.1 Opening geometry

3.1.13 Where circular corners are arranged, a radius not less than 1/20 of the breadth of the opening is to be used with a minimum of 75 mm. For circular corners, inserts of the size and extent shown in Fig. 2.3.2 will, in general, be required. The thickness of insert plates is to be not less than 25 per cent greater than the adjacent plating with a minimum increase of 4 mm. The increase need not exceed 7 mm.

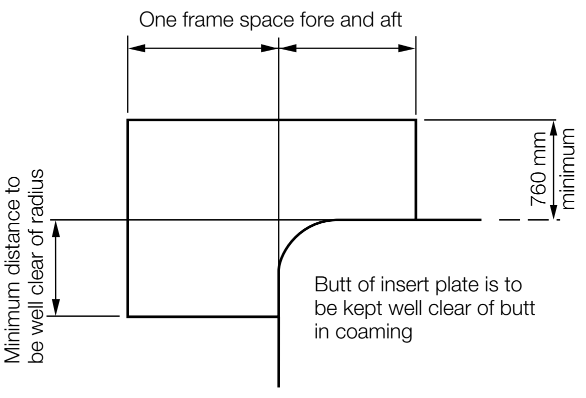


Fig. 2.3.2 Inserts in way of openings

3.1.14 For other shapes of corner, inserts of the size and extent shown in Fig. 2.3.2 will, in general, be required.

3.1.15 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory. The size of openings are to be in accordance with 3.2.9.

3.1.16 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.1.17 Provision is made for the free passage of air and water taking into account the pumping rates required.

3.1.18 Particular care is to be given to the positioning of drain holes to reduce stress concentrations and ensure adequate drainage from all parts of the ship's hull to the suctions. They are to be placed as close to the bottom as practicable.

3.1.19 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes. They are to be placed as close to the top of the tank as practicable. Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 3, Ch 4,6.

3.1.20 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted.

3.1.21 Widely spaced air or drain holes, cut entirely in the web adjacent to, but clear of the welded connection, may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentrations, *see* Fig. 2.3.3.

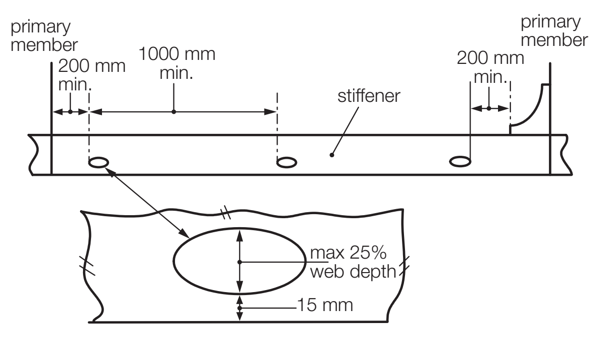


Fig 2.3.3 Air/Drain hole geometry

3.2 Primary members

3.2.1 The following guidelines for the design of primary members are to be adopted. Scantling requirements for primary members are given in Pt 6, Ch 3.

3.2.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members are to form a continuous line of support and, wherever possible, a complete ring system.

3.2.3 Primary members are to have adequate lateral stability and web stiffening and the stiffening structure is to be arranged to minimise hard spots and other sources of stress concentration.

3.2.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member. Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

3.2.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

3.2.6 Where primary members are subject to concentrated loads, particularly if these loads are out of line with the member web, additional strengthening may be required.

3.2.7 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Brackets are generally required but alternative arrangements will be considered.

3.2.8 The thickness of the brackets supporting primary members is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

3.2.9 Where openings are cut in the web or primary members, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

3.2.10 Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel in which they are situated.

3.2.11 Cut-outs for the passage of secondary members are to be designed to minimise the creation of stress concentrations. The breadth of cut-out is to be kept as small as practicable and the top edge is to be rounded, or the corner radii made as large as practicable. The extent of the direct connection to the web plating, or the scantlings of lugs or collars, is to be sufficient for the loads to be transmitted from the secondary member, *see also* Pt 6, Ch 6,5.3.

3.2.12 Stiffeners in areas likely to experience slamming, impact or dynamic loads are to be lugged or bracketed to the web of the primary member at their intersections, *see also* Pt 6, Ch 6,5.3.

3.3 Shell plating

3.3.1 Scantling requirements for shell plating are given in Pt 6, Ch 3,5.

3.3.2 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.3.3 In general, openings are not to be cut in the sheerstrake, however, if operational requirements dictate, openings that are less than 20 per cent of the depth of the sheerstrake may be accepted. Openings greater than 20 per cent of the depth of the sheerstrake will require special consideration.

3.3.4 Where large side shell openings, such as side aircraft lifts, are proposed, detailed calculations are to be submitted.

3.3.5 Where rounded gunwales are fitted, arrangements are to ensure a smooth transition from rounded gunwale to angled gunwale.

3.3.6 At the ends of superstructures where the side plating is extended and tapered to align with the bulwark plating, the transition plating is to be suitably stiffened and supported. Where freeing ports or other openings are essential in this plate, they are to be suitably framed and kept well clear of the free edge.

3.3.7 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings. Additional thickness is to be required in accordance with Pt 6, Ch 3, 5.7. Adequate provision is to be taken to prevent local resonance problems. Additional guidance for the design of sea-inlets or other openings, is given in Pt 4, Ch 1,8.

3.3.8 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be kept clear of weld connections.

3.3.9 The scantlings of appendages (e.g. ‘A’ brackets) are covered in Chapter 3. However, in way of the hull penetrations, particular care will be required to be given to the strength and watertight integrity of the shell.

3.4 Shell framing

3.4.1 The scantlings of shell structure are to be determined in accordance with Pt 6, Ch 3,6.

3.4.2 Longitudinal framing is, in general, to be adopted in the bottom, but special consideration will be given to proposals for transverse framing in this region, *see* 3.1.4.

3.4.3 For NS1 and NS2 ships, the bottom and side longitudinals are to be continuous in way of both watertight and non-watertight floors, but equivalent arrangements will be specially considered.

3.4.4 Bottom and side longitudinals are to be supported by primary transverse structure such as bottom transverses, floors or bulkheads, generally spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.4.5 Bottom and side transverses, where fitted, are to be continuous and substantially bracketed at their end connections to side and deck transverses and bottom floors.

3.4.6 Bottom and side frames are to be effectively continuous and bracketed at their end connections to side frames, deck beams and bottom floors as appropriate. Side frames are to be supported by decks or stringers spaced not more than three metres apart.

3.4.7 Bottom girders and side stringers supporting transverse frames, are to be continuous through transverse bulkheads and supporting structures. They are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than three metres apart.

3.4.8 For primary members the web stability, openings in the web and continuity and alignment are to be in accordance with 3.2.9.

3.4.9 For ships intended for beach landing operations, *see* Pt 4, Ch 2,8.

3.4.10 For berthing and docking requirements, *see* Vol 1, Pt 3, Ch 5,11.

3.4.11 Where the shell framing is of unusual design or proportions, the scantlings are to be determined by direct calculation.

3.5 Single bottom structure

3.5.1 Scantling requirements for single bottom structure are given in Pt 6, Ch 3,7.

3.5.2 The requirements of this section provide for single bottom construction in association with transverse and longitudinal framing systems, *see* 3.1.4.

3.5.3 All girders are to extend as far forward and aft as necessary and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, alignment and longitudinal strength are to be maintained.

3.5.4 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

3.5.5 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the ship, *see* Pt 4, Ch 2,8.

3.5.6 A continuous centreline girder is, in general, to be fitted in all ships throughout the length of the hull as far forward and aft as practicable.

3.5.7 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. In general, side girders where fitted are to be continuous, extend as far forward and aft as practicable and to terminate in way of bulkheads, deep floors or other primary transverse structure. In addition, continuous intercostal longitudinal stiffeners are to be fitted where the panel size exceeds the ratio 4 to 1.

3.5.8 In ships with a transversely framed bottom construction, the bottom shell plating is, in general, to be reinforced with additional continuous, or intercostal, longitudinal stiffeners. Alternative arrangements to be considered.

3.5.9 For ships intended for beach landing operations, *see* Pt 4, Ch 2,8.

3.5.10 In longitudinally framed ships, plate floors are to be fitted as given in 3.4.4. The connections with side transverse web frames are to be as required by 3.4.6. Additional transverse floors or webs are in general to be fitted at the half spacing of primary transverse structure in way of engine seatings, thrust bearings, pillars, skegs, bilge keels and the bottom of the ship forward.

3.5.11 The tops of the floors may be level from side to side. However, in ships having considerable rise of floor the depth of floors may require to be increased to maintain the required section modulus.

3.5.12 In general, the floors in way of the stern tubes, shaft brackets, etc., are to provide effective support for these items.

3.6 Double bottom structure

3.6.1 Scantlings of double bottoms are to be in accordance with Pt 6, Ch 3,8.

3.6.2 Double bottoms are in general to be fitted in NS1 ships and are to extend from the collision bulkhead to the aft peak bulkhead, as far as this is practicable within the design and proper working of the ship. The subdivision standard specified by the Naval Authority adopted in accordance with 1.3 may contain additional requirements for the height and extent of the double bottom.

3.6.3 A double bottom is generally not required in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not thereby impaired. Suitable scarfing arrangements are to be made to maintain continuity of the inner bottom.

3.6.4 The inner bottom is to be continued to the ship's side as far as practicable, in such a manner as to protect the bottom to the turn of bilge or chine.

3.6.5 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, their alignment and longitudinal strength is to be maintained.

3.6.6 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the ship. Other well arrangements (e.g. for lubricating oil under main engines) may also be considered provided they give protection equivalent to that afforded by the double bottom.

3.6.7 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. Openings are to be in accordance with 3.2.9.

3.6.8 The number and position of manholes are to be such that access under service conditions is neither difficult nor dangerous.

3.6.9 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.6.10 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.6.11 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.6.12 A plan showing the location of manholes and access openings within the double bottoms is to be submitted.

3.6.13 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. Details are given in 3.1.15.

3.6.14 Air and drain holes, notches and scallops are to be in accordance with 3.1.7.

3.6.15 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.6.16 In way of ends of floors and girders and transverse bulkheads, the number and size of holes are to be kept to a minimum, the openings are to be circular or elliptical and edge stiffening may be required.

3.6.17 Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the ship or where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

3.6.18 Centreline and side girders are to be continuous and sufficient to withstand the forces imposed by dry-docking the ship, *see* Part 4. Vertical stiffeners are to be fitted at every bracket floor.

3.6.19 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m (for transversely framed ships, 5 m for longitudinally framed ships).

3.6.20 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

3.6.21 Plate floors are, in general, to be continuous between the centre girder and the margin plate. Vertical stiffeners are to be fitted to the floors, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

3.6.22 In longitudinally framed ships, plate floors or equivalent structure are, in general, to be fitted in accordance with 3.4.4 and additionally at the following positions:

(a) At every half spacing of primary transverse structure as given in 3.4.4, in way of the bottom of the ship forward of $0{,}8L_R$.

(b) Underneath pillars and bulkheads.

3.6.23 In transversely framed NS3 ships, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 1,5 m.

3.6.24 Between plate floors, the shell and inner bottom are to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

3.6.25 In longitudinally framed ships, the bracket floors are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket floor to be taken as less than 75 per cent of the depth of the centre girder. They are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

3.6.26 In transversely framed ships, the breadth of the bracket floors, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder, *see* Fig. 1.5.4(b) in Chapter 1.

3.6.27 Inner bottom longitudinals are to be supported by inner bottom transverses, floors, bulkheads or other primary structure, generally spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.6.28 The inner bottom longitudinals are to be continuous through the supporting structure.

3.6.29 Inner bottom transverses are to be continuous and to be substantially bracketed at their end connections to bottom transverses, bottom floors and tank side brackets.

3.6.30 In general, whilst the fitting of pillars connecting to the inner bottom is to be avoided, where they are fitted, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided. Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

3.6.31 Double bottoms are to be tested in accordance with the requirements of Vol 1, Pt 6, Ch 6,6 of the Rules.

3.6.32 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.7 Deck structure

3.7.1 Scantlings of decks are to be in accordance with the requirements of Pt 6, Ch 3,10.

3.7.2 Where an inner bottom is not fitted, consideration of the ship's stability and strength following bottom damage is required. It may be appropriate to consider designing the lowest deck to be watertight. This is to be determined in conjunction with the damage stability analysis, assuming bottom damage.

3.7.3 The deck plating is to be supported by transverse beams with fore and aft girders; by longitudinals with deck transverses, or alternatively, by a grillage system of orthogonal and primary structure as provided for in 3.1.1. The transverse beams and deck transverses are to align with side main frames and side transverses respectively. For NS1 and NS2 ships, longitudinal framing is generally to be adopted, *see* 3.1.4.

3.7.4 Where transversely stiffened, beams are to be fitted at every frame and bracketed to the side frames. Deck transverses should also to be fitted at the ends of large openings in the deck.

3.7.5 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

3.7.6 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

3.7.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

3.7.8 Arrangements to prevent tripping are to be fitted on deep webs.

3.7.9 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, and deck equipment or machinery.

3.7.10 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as out of line pillars, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

3.7.11 The end connection of strength deck longitudinals to bulkheads are to provide adequate fixity and, so far as is practicable, direct continuity of longitudinal strength. For NS1 and NS2 ships, the strength deck longitudinals are to be continuous through transverse structure, including bulkheads, but alternative arrangements will be considered.

3.7.12 Transverses supporting deck longitudinals are, in general, to be spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships. They are to be aligned with primary side structure.

3.7.13 All openings are to be supported by an adequate framing system, pillar bulkheads or cantilevers. When cantilevers are used, the scantlings are to be determined by direct calculation.

3.7.14 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates, in such a way as to minimise stress concentrations.

3.7.15 Other openings in the strength deck outside the line of major openings are to be kept to the minimum number consistent with operational requirements. Openings are to be arranged clear of other opening corners and, so far as possible, clear of one another. Where necessary, plate panels in which openings are cut are to be adequately stiffened against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth. Attention is to be paid to structural continuity and abrupt changes of shape, section or thickness are to be avoided.

3.7.16 Gutterway bars and spurn waters at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and that they do not cause stress concentrations in the deck or sheerstrake, *see also* Pt 6, Ch 3,3.6.

3.7.17 It is recommended that the working areas of the weather deck have an anti-slip surface. Working areas of all decks where there is the possibility of leakage of fuel, hydraulic or other oils are to be provided with anti-slip deck coatings, or equivalent, and guard rails, as appropriate.

3.7.18 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Part 6.

3.7.19 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

3.7.20 Where large side shell openings, such as side aircraft lifts, are proposed, detailed calculations are to be submitted.

3.7.21 Pipe or cable runs through watertight decks are to be fitted with suitable watertight glands.

3.7.22 Doors and hatches fitted in watertight decks are to be of equivalent construction to the deck in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the deck. They are to be tested watertight in accordance with the LR survey procedures.

3.8 Deep tank structure

3.8.1 The scantlings of deep tank structure are to be in accordance with the relevant sections of Part 6.

3.8.2 Above the top of floors, the side shell structure of deep tanks is to be effectively supported by a system of primary framing with web frames, stringers, cross ties and/or perforated flats.

3.8.3 The maximum spacing of side shell transverses in longitudinally framed deep tanks is generally not to exceed 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.8.4 The maximum spacing of side shell web frames in transversely framed deep tanks is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

3.8.5 The maximum spacing of horizontal stringers is generally not to exceed 3,0 m.

3.8.6 Where decks terminate at deep tanks suitable scarfing arrangements are to be arranged and the side shell supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners are to be supported at the deck level against tripping.

3.8.7 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of Part 6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of Part 6 for wash plates. The area of perforation is to be not less than five per cent nor more than 10 per cent of the total area of the bulkhead. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

3.8.8 The thickness of any longitudinal bulkheads may be required to be increased to ensure compliance with the shear strength requirements of Part 6. In the case of a centreline or perforated wing bulkhead, the proportion of the total shear force absorbed by the bulkhead will be specially considered.

3.8.9 The thickness of plating of wash bulkheads may also be required to be increased to take account of shear buckling.

3.8.10 Where longitudinal wash bulkheads support bottom transverses, the lower section of the bulkhead is to be kept free of non-essential openings for a depth equal to 1,75 times the depth of the transverses. The plating is to be assessed for local buckling requirements.

■ *Section 4* Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads for NS2 and NS3 ships are, in general, to extend to the uppermost continuous deck, and their construction is to be in accordance with Pt 6, Ch 3,9. In the larger multidecked NS1 ships (e.g. Aircraft Carriers) the watertight bulkheads are generally to extend to the lowest continuous vertical limit of weathertightness determined by 1.3.

4.1.2 Certain openings below the deck given in 4.1.1 may be permitted by the relevant stability and subdivision standard, but these must be kept to a minimum and provided with means of closing to watertight standards.

4.1.3 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted if acceptable to the Naval Authority. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. In such cases access is to be by manholes with closely spaced bolts situated as high as possible above the design waterline and, in any event, no lower than the damage control deck.

4.1.4 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4,7.

4.1.5 Bulkheads forming the boundaries to citadels and zones as defined in Pt 4, Ch 1,7 other than watertight bulkheads, are usually required by the Naval Authority to be gastight. *See also* 4.8. Where specifically required by the Naval Authority, LR can access the gastight integrity of defined gastight boundaries, *see* Vol 1, Pt 6, Ch 6,6.8.

4.1.6 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

4.1.7 Partial or main bulkheads are to be located beneath the ends of superstructures and deckhouses and masts and heavy items of equipment such as weapon systems to support and transmit the static and dynamic forces into the hull structure. They are to be of sufficient strength and rigidity to carry the concentrated loads imposed on them and maintain alignment where necessary.

4.2 Number and disposition of watertight bulkheads

4.2.1 In general, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with Naval Authority requirements as defined in 1.3.

4.2.2 Main transverse watertight bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually large, the transverse strength of the ship is to be maintained by fitting of web frames, increased framing, etc. Details of the proposed arrangements are to be submitted.

4.2.3 All ships are to have a collision bulkhead, an after peak bulkhead and a watertight bulkhead at each end of all main and auxiliary machinery spaces. Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

Table 2.4.1 Minimum number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft *see* Note
$L_R \leq 65$	4	3
$65 < L_R \leq 85$	4	4
$85 < L_R \leq 90$	5	5
$90 < L_R \leq 105$	5	5
$105 < L_R \leq 115$	6	5
$115 < L_R \leq 125$	6	6
$125 < L_R \leq 145$	7	6
$145 < L_R \leq 165$	8	7
$165 < L_R \leq 190$	9	8
$L_R > 190$	To be considered individually	

NOTE
With after peak bulkhead forming after boundary of machinery space.

4.2.4 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the operational requirements.

4.2.5 A main transverse bulkhead is to be located at the position where the ship sues during docking.

4.3 Collision bulkheads

4.3.1 The collision bulkhead is to be positioned as detailed in Table 2.4.2. However, consideration will be given to proposals for the collision bulkhead to be positioned slightly further aft on an arrangement (b) ship, but not more than $0,08L_R$ from the fore end of L_R, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the bulkhead deck becoming submerged, or any unacceptable loss of stability. The length L_R is as defined in Table 2.4.1.

Table 2.4.2 Collision bulkhead position distance of collision bulkhead aft of fore end of L_R, in metres

Arrangement	Length L_R, in metres	Minimum	Maximum
(a)	≤ 200 > 200	$0,05L_R$ 10	$0,08L_R$ $0,08L_R$
(b)	≤ 200 > 200	$0,05L_R - f_1$ $10\text{m} - f_2$	$0,08L_R - f_1$ $0,08L_R - f_2$

Symbols and definitions
f_1 = $G/2$ or $0,015L_R$, whichever is the lesser
f_2 = $G/2$ or 3 m, whichever is the lesser
G = projection of bulbous bow forward of fore perpendicular, in metres
Arrangement (a) A ship that has no part of its underwater body extending forward of the fore perpendicular
Arrangement (b) A ship with part of its underwater body extending forward of the fore perpendicular, (e.g. bulbous bow)

4.3.2 For ships with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.4 Aft peak bulkhead

4.4.1 NS1 and, where practicable, NS2 ships, are to have an aft peak bulkhead generally enclosing the sterntube and rudder trunk in a watertight compartment. In twin screw ships where the bossing ends forward of the aft peak bulkhead, the sterntubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. The stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the ship will remain fully operational. The arrangement in NS3 ships, and in NS2 ships where it is impracticable to meet the aforementioned conditions, will be specially considered based on the integrity of the gland sealing arrangements and damage stability requirements.

4.5 Height of bulkheads

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of a ship with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the first deck above the vertical limit of watertight integrity. Where the collision bulkhead extends above the vertical limit of watertight integrity, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor.

4.5.3 The remaining watertight bulkheads are to extend as required by 4.1.1. In ships of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats, openings and loading ramps

4.6.1 Watertight recesses in bulkheads are to be avoided whenever possible.

4.6.2 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration.

4.6.3 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight in accordance with the LR Survey Procedures.

4.6.4 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1. If a step occurs above the virtual limit of watertight integrity the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.5 Doors, manholes, permanent access openings or ventilation ducts are not to be cut in the collision bulkhead except as provided for in 4.1.3.

4.6.6 In ships fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the virtual limit of watertight integrity, that part of the ramp which is more than 2,30 m above the virtual limit of watertight integrity may extend forward of the minimum limit specified in Table 2.4.2. Such a ramp is to be weathertight over its complete length.

4.7 Watertight doors in bulkheads below the vertical extent of watertightness

4.7.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the ship is listed up to 15° either way. They are to be operated under working conditions and hose tested in place, *see* Pt 6, Ch 3.

4.7.2 Watertight doors of the sliding type are to be capable of being operated by efficient hand operated gear, both at the door itself and from an accessible position above the vertical limit of watertight integrity. Means are to be provided at the remote operating position to indicate whether the door is open or closed. The lead of shafting is to be as direct as possible and the screw is to work in a gunmetal nut, *see also* 4.11.1.

4.7.3 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested from both sides for the maximum head of water indicated by any required damage stability calculations.

4.7.4 Indicators are to be provided on the bridge or operations room showing whether the doors are open or closed.

4.7.5 Doors are to be capable of being operated from both sides of the bulkhead and from an accessible position above the vertical limit of watertight integrity. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

4.7.6 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to fixed on the closing appliance saying it should be kept closed at all times while the ship is at sea.

4.7.7 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

4.7.8 As an alternative to the sliding doors required by 4.7.7, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

4.7.9 Subject to the requirements of 4.7.7 and 4.7.8, hinged weathertight doors of approved pattern may be fitted above the damage control deck to provide access.

4.7.10 Each watertight door is to be subject to a pressure test, *see* Pt 6, Ch 3. The test may be carried out either before or after the door is fitted.

4.8 Gastight bulkheads

4.8.1 Where an assessment of gastight integrity is required the scantlings of gastight bulkheads are to be in accordance with Part 6.

4.8.2 Where bulkheads are required to be gastight and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.9 Tank bulkheads

4.9.1 For bulkheads in way of partially filled compartments or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

4.9.2 The scantlings of deep tank bulkheads are to be in accordance with Part 6.

4.9.3 Air and sounding pipes are to comply with the requirements of Pt 3, Ch 4,6.

4.10 Cofferdams

4.10.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying fresh water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

4.10.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel unless:
(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.
(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.10.3 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from a machinery or hazardous space fire.

4.10.4 Adequate access is to be provided to all parts of the cofferdams for future maintenance, surveys and repairs. The edges of openings are to be smooth.

4.11 Watertight tunnels and passageways

4.11.1 Sterntubes are to be enclosed in watertight spaces of moderate volume. In addition, arrangements are to be made to minimise the danger of water penetrating into the ship in case of damage to the stern tube in accordance with the requirements of the Naval Authority. Normally the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the vertical limit of watertight integrity, *see* Pt 3, Ch 2,1.3, will not be submerged.

4.12 Means of escape

4.12.1 The arrangement of the hull is to be such that all under deck compartments are as accessible as practicable and provided with a satisfactory means of escape in accordance with a recognised Naval Authority. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.13 Carriage of low flash point fuels

4.13.1 For ships having oil fuel with a flash point below 60°C the arrangement for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the ship and persons on board is preserved, having regard to the fire and explosion hazards. *See* Vol 2, Pt 7, Ch 3,2.

■ *Section 5* Fore and aft end arrangements

5.1 General

5.1.1 In general the main hull structural arrangements as defined in 3,3 are to extend as far forward and aft as possible.

5.1.2 The requirements of this section apply to the fore and aft ends and relate to structure situated in the region forward of $0{,}7L_R$ and aft of $0{,}3L_R$ respectively.

5.1.3 Certain ships will require additional strengthening for bottom forward slamming and bow flare slamming. The scantlings of the hull structure forward are to be determined from Part 6, using the loads specified in Pt 5, Ch 3,3.

5.1.4 Where the stern overhang is significant, or large masses are placed on the stern, the strength of the aft end structure will be specially considered, *see* Vol 1, Pt 3, Ch 5,11.2.

5.2 Structural continuity

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.2.2 Where the shell, deck and inner bottom are longitudinally framed in the midship region, this system of framing is to be carried forward and aft as far as possible.

5.2.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and as far as practicable, direct continuity of longitudinal strength, *see also* Section 3.

5.2.4 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.2.5 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending forwarded from 0,85L_R, longitudinal framing at the upper deck and topsides is generally to be continued forward of the aft bulkhead of this superstructure.

5.2.6 Where a superstructure or poop is fitted extending forward of 0,15L_R, longitudinal framing at the upper deck and topsides is generally to be continued aft of the forward bulkhead of this superstructure.

5.2.7 The forecastle side plating may be a continuation of the side shell plating or fitted as a separate assembly. The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

5.2.8 Forecastles and bulwarks are to be constructed in accordance with the scantlings indicated in Pt 6, Ch 3,11.

5.3 Minimum bow height and extent of forecastle

5.3.1 The requirements regarding minimum bow height given in 5.3.2 are to be complied with. Only in exceptional circumstances and in specialist ships will any relaxation be given to this requirement where it interferes with the safe operation of the vessel. In such cases due consideration is to be given to the clearing of seawater from the forecastle deck. The effects on strength and stability are also to be considered.

5.3.2 All sea-going ships are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the waterline design draught to the top of the exposed deck at side at the F.P. is not less than:

For ships less than 250 m in length:

$$H_b = 56L_R\left(1 - \frac{L_R}{500}\right)\left(\frac{1,36}{C_b + 0,68}\right) \text{ mm}$$

For ships 250 m and above in length:

$$H_b = 7000\left(\frac{1,36}{C_b + 0,68}\right) \text{ mm}$$

where

C_b = block coefficient which is not to be less than 0,68 for this calculation

H_b = minimum bow height, in mm

L_R = Rule length.

5.3.3 Ships which are designed to suit exceptional operational requirements, restricted in their service to service area **SA4**, or of novel configuration will be specially considered on the basis of the Rules.

5.3.4 Where the bow height required in 5.3.2 is obtained by increased sheer, the sheer shall extend for at least 15 per cent of the length of the ship measured abaft the forward end of L_R. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_R abaft the forward end of L_R.

5.4 Bow crumple zone

5.4.1 In general the bow crumple zone is that space forward of the collision bulkhead. Embarked personnel or crew accommodation and the carriage of fuel, hazardous materials and other oils is not permitted in the bow crumple zone.

5.5 Deck structure

5.5.1 The scantlings of the deck structure are to comply with Pt 6, Ch 3,10.

5.5.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of anchor windlass, other deck machinery, and in way of cranes, masts or derrick posts, RAS stump masts, and weapon launching positions, etc.

5.5.3 Where large openings are arranged at lower decks near the side shell, it may be necessary to increase the adjacent deck structure to ensure effective support for side framing.

5.5.4 In NS1 and NS2 ships, on decks aft of the after cut-up, deep beams are generally to be fitted in way of web frames. Deck girders are generally to be spaced not more than 3,0 m apart and integrated with the primary structure forward.

5.5.5 Requirements for the arrangement and geometry of deck openings are given in 3.1 and 3.7. The scantlings of any inserts required are to be in accordance with Part 6.

5.6 Shell envelope plating and framing

5.6.1 The scantlings of bar keels in the forward end are to be the same as that required in the midship region, *see* Pt 6, Ch 3, Table 3.2.1.

5.6.2 The thickness and width of plate keels in the forward region are to be the same as that required in the midship region.

5.6.3 The scantlings of plate stems are to be determined from Pt 6, Ch 3,5. Plate stems are to be supported by horizontal diaphragms positioned in line with the side stringers or perforated flats with intermediate breasthook diaphragms. Diaphragms are to be spaced not more than 1,5 m apart, measured along the stem. Where the stem plate radius is large, a centreline stiffener or web will be required.

5.6.4 The thickness of side shell and sheerstrake plating in the forward region is to be not less than the values required by Pt 6, Ch 3,5, but may be required to be increased locally on account of high shear forces, in accordance with Pt 6, Ch 4,3.2.

5.6.5 The shell plating may be required to be increased in thickness locally in way of openings such as hawse pipes and sonar domes, where fitted.

5.6.6 The shell plating is to be increased in thickness locally in way of a bulbous bow, *see* 5.10.

5.6.7 Sea inlet and other openings are to be in accordance with 3.3.6.

5.6.8 The bottom longitudinals are to be continuous in way of both watertight and non-watertight floors.

5.6.9 Where the shape of the after hull is such that there are large flat areas, particularly in the vicinity of the propellers, additional primary supports for the secondary stiffening may be required. Their extent and scantlings will be specially considered.

5.7 Single and double bottom structure

5.7.1 The general requirements of 3.5 and 3.6 apply.

5.7.2 The minimum depth of centre girder forward is generally to be the same as that required in the midship region.

5.7.3 Where the height of the double bottom varies, structural continuity is to be maintained. An inner bottom where fitted is to be gradually sloped over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.7.4 For ships of full form, in fore peak and deep tank spaces, the floors and bottom transverses are to be supported by a centreline girder or a centreline wash bulkhead. In other cases the centreline girder is to be carried as far forward as practicable. The floor panels and the upper edges of the floors and centreline girder are to be suitably stiffened.

5.7.5 In aft peak spaces, floors are to be arranged at every frame. For details and scantlings, *see* Pt 6, Ch 3,7.

5.7.6 Provision is to be made for the free passage of water and air from all parts of single or double bottoms as required by 3.1.17 to 3.1.21.

5.8 Fore peak structure

5.8.1 The requirements given in this Section apply to the arrangement of primary structure supporting the fore peak side shell and bulbous bow, the arrangement of wash bulkheads and perforated flats. The scantlings of structure in the fore peak is to be in accordance with the relevant sections of Part 6.

5.8.2 The bottom of the peak space is generally to be transversely framed. Longitudinally framed bottom structure will be specially considered.

5.8.3 Above the floors, transverse side framing is to be supported by horizontal side stringers, cross ties and/or perforated flats.

5.8.4 Suitable transverses or deep beams are to be arranged at the top of the tank and at perforated flats to provide end rigidity to the side transverses.

5.8.5 Wash bulkheads are to have an area of perforations not less than five per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings. Stiffeners are to be bracketed at top and bottom.

5.9 Aft peak structure

5.9.1 The scantlings of aft peak structure are to be as required by the relevant sections of Part 6. The plating thickness is to be increased locally in way of the sterntube gland.

5.9.2 Floors are to be arranged at every frame space and are to be carried to a suitable height, and at least to above the stern tube, where fitted. Floors are to be adequately stiffened. In way of propeller shaft brackets, rudder post or rudder horn, the floors are generally to be carried to the top of the space and are to be of increased thickness. The extent and amount of the increase will be specially considered, account being taken of the arrangements proposed.

5.9.3 Above the floors, transverse side framing is to be supported by horizontal stringers, cross ties and/or perforated flats.

5.9.4 Suitable transverses or deep beams are to be arranged at the top of the tank to provide end rigidity to the side transverses.

5.9.5 A centreline wash bulkhead is to be arranged in the upper part of the aft peak space. Additional wash bulkheads are to be fitted port and starboard where the width of the tank exceeds 20 m.

5.9.6 The plating is to be suitably stiffened in way of openings, and the arrangement of openings is to be such as to maintain adequate shear rigidity.

5.9.7 The position and height of the after peak bulkhead are to be in accordance with the requirements of 4.4.

5.9.8 Centre and side girders where fitted are to be bracketed to the transom framing members by substantial knees. Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is attached can satisfactorily carry the load.

5.10 Bulbous bows

5.10.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.10.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.10.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.10.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.10.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.10.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

■ *Section 6*
Machinery space arrangements

6.1 General

6.1.1 Requirements particular to machinery spaces, including protected machinery casings and engine seatings only, are given in this Section. For other scantlings and arrangement requirements, *see* the relevant section in this Chapter.

6.1.2 Requirements for the scantlings of structure in machinery spaces are to be in accordance with the relevant sections of Pt 6, Ch 3,13.

6.2 Structural configuration

6.2.1 Requirements are given for ships constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 Machinery space stiffening is generally to be arranged in the same manner as structure immediately forward and aft of the space. For NS1 and NS2 ships this will generally be longitudinal. Machinery spaces adjacent to the aft peak bulkhead may be constructed using a transverse framing system or a combination of longitudinal and transverse.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the ship is omitted in way of a machinery space.

6.3.2 Where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 Where a transverse framing system is adopted, deck beams are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Deep beams are to be arranged in way of the ends of engine casings and also in line with side web frames where fitted.

6.4.3 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in association with pillars or pillar bulkheads. The maximum spacing of transverses is give in 6.5.2. Deck transverses are to be in line with side transverses or web frames.

6.4.4 Machinery casings are to be supported in accordance with the requirements of 6.7.

6.4.5 The scantlings of lower decks or flats are generally to be as given in Pt 6, Ch 3,10. However, in way of concentrated loads such as those from boiler bearers or heavy auxiliary machinery, etc., the scantlings of deck structure will be specially considered, taking account of the actual loading.

6.4.6 In way of machinery space openings, etc., particularly towards the aft end, decks or flats are to have sufficient strength where they are intended to provide effective primary support to side framing, webs or transverses.

6.4.7 Where decks terminate at a machinery space bulkhead, suitable scarfing arrangements are to be arranged. The side shell of the machinery space is generally to be supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners at the deck level are to be supported against tripping.

6.4.8 Machinery space bulkheads with no supporting decks are to have suitable primary stiffening similar to that provided for the side shell in 6.5.

6.5 Side shell structure

6.5.1 The side shell structure of machinery spaces is to be effectively supported by a system of primary framing with web frames and stringers. General requirements for web frames are given in this Section for both longitudinal and transverse framing systems.

6.5.2 The maximum spacing of side shell transverses in longitudinally framed machinery spaces is generally not to exceed 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships.

6.5.3 The maximum spacing of side shell web frames in transversely framed machinery spaces is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

6.5.4 The maximum spacing of stringers is generally not to exceed 3,0 m.

6.6 Double and single bottom structure

6.6.1 For the required extent of double bottom structure, *see* 3.6.

6.6.2 In the bottom structure sufficient fore and aft girders are to be arranged in way of the main machinery to effectively distribute its weight and to ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing. This extension beyond the after bulkhead of the machinery space is to be for at least three transverse frame spaces, aft of which the girders are to scarf into the structure. Forward of the forward machinery space bulkhead, the girders are to be tapered off over three frame spaces and effectively scarfed into the structure. In machinery spaces in the aft end of the ship the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Care is to be taken to avoid any abrupt changes or discontinuities.

6.6.3 Where, in NS3 ships, the bottom is transversely framed, plate floors are to be fitted at every frame in the machinery space and under the main machinery, rafts, seatings and thrust bearing.

6.6.4 Where the bottom is longitudinally framed, plate floors are to be fitted at a maximum spacing of 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships in the machinery space under the main machinery, rafts, seatings and thrust bearing.

6.6.5 The minimum depth of the centre girder and its thickness are to be at least the same as required in way of other spaces amidships. Where the height of inner bottom in the machinery spaces differs from that in adjacent spaces, continuity of longitudinal material is to be maintained. In ships with a double bottom it is to be achieved by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the plating are to be arranged close to plate floors.

6.6.6 Margin plates and drainage wells are to be provided as necessary and will be subject to special consideration.

6.6.7 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions. General requirements are given in 3.1.17 to 21.

6.6.8 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.6.9 Where practicable side girders outboard of the engines are to be fitted and are to line up with the side girders in adjacent spaces.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Pt 6, Ch 3,11.

6.7.2 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.3 Machinery casings are to be supported by a suitable arrangement of deep beams or transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may by required, and these are to be arranged in line with deep beams or transverses. Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Pt 6, Ch 3,9.

6.8.2 Oil fuel tanks situated within the machinery space are generally to comply with the requirements given in Part 6.

6.9 Machinery seatings

6.9.1 Requirements on the scantlings of structure for machinery seatings is given in Pt 6, Ch 3,13.

6.9.2 This section applies to machinery or machinery raft seatings that are directly supported by the ship's hull. They are to be effectively secured to the hull and to be of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them. Due attention is to be paid to the stiffness requirements of the machinery or raft supported.

6.9.3 Seatings are to be of substantial construction and efficiently supported by transverse and horizontal brackets or gusset plates. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at upper decks. Where applicable seats are to be designed to ensure proper alignment with gearing and allow for thermal expansion effects.

6.9.4 In general seats are not to be arranged in way of breaks or recesses in the bottom structure.

6.9.5 Main machinery or raft holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, additional floors are to be fitted.

6.9.6 Auxiliary machinery is to be secured on seating of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

■ *Section 7* Superstructures, deckhouses, bulwarks, sponsons and appendages

7.1 General

7.1.1 Superstructures, deckhouses, forecastles and bulwarks are to be constructed in accordance with the scantlings indicated in Pt 6, Ch 3,11.

7.1.2 For requirements relating to companionways, doors, accesses and skylights, *see* Pt 3, Ch 4.

7.1.3 Requirements for machinery casings are given in 6.7.

7.1.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

7.2 Definitions

7.2.1 The term ‘house’ is used to include both superstructures and deckhouses.

7.2.2 The lowest, or first tier of a house, is normally that which is directly situated on the deck to which, *D*, is measured. The second tier is the next tier above the lowest tier and so on.

7.3 Structural requirements

7.3.1 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, equipment, fittings and other heavy or vibrating loads.

7.3.2 Structures subject to concentrated loads are to be suitably reinforced. Where a concentration of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

7.3.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

7.3.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

7.3.5 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

7.3.6 Web frames or partial bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

7.3.7 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations. The house stiffening is to align with main hull stiffening wherever possible.

7.3.8 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

7.3.9 Adequate support under the ends of houses is to be provided in the form of webs, pillars and diaphragms or bulkheads in conjunction with reinforced deck beams. At the corners of houses and in way of supporting structures attention is to be given to the connection to the decks and inserts or equivalent arrangements should generally be fitted.

7.4 Openings

7.4.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in houses. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits and cranes.

7.4.2 Particular care is to be paid to the effectiveness of end bulkheads and the upper deck stiffening in way when large openings are fitted.

7.4.3 Special care is to be taken to minimise the size and number of openings in the sides or longitudinal bulkheads of houses which end within $0,25L_R$ to $0,75L_R$. Account is to be taken of the high vertical shear loading which can occur in these areas.

7.4.4 Windows, ventilators and other superstructure openings are to be suitably framed and mullions will in general be required.

7.5 Effective structure

7.5.1 For ships where L_R exceeds 40 m or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Pt 6, Ch 4,2.5.

7.5.2 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment of structural efficiency may be required. The scantlings of the side structure in way of these areas may also be required to be increased.

7.6 Sponsons and appendages

7.6.1 Primary structure supporting sponsons is to be effectively integrated into the main hull structure. This is to be achieved by extending the primary framing system or by suitable scarfing the sponson primary structure over at least five frame spaces.

7.6.2 The scantlings of sponson structure are to be as required by the relevant parts of Part 6, for decks or side shell. Decks used for aircraft operations or wheeled vehicles are to comply with Part 4 and Part 6 respectively.

7.6.3 Where sponsons are located outside of $0{,}4L_R$ amidships and extend outside of the waterline breadth, B_{WL}, of the ship the effects of wave impacts are to be considered. The loads are to be derived in accordance with the bow flare slamming requirements in Pt 5, Ch 3,3.

7.6.4 The strength and arrangement of large bilge keels, stabilizers and other protrusions that may impinge on icebergs or flows are to be specially considered. In some cases the speed for operation in ice may be restricted.

7.7 Unusual designs

7.7.1 Ships or structural arrangements which are of unusual design, form or proportions will be individually considered.

■ *Section 8* Pillars and pillar bulkheads

8.1 General

8.1.1 Pillars and pillar bulkheads are to be constructed in accordance with the scantlings indicated in Pt 6, Ch 3,12.

8.1.2 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

8.2 Head and heel connections

8.2.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

8.3 Alignment and arrangement

8.3.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses, large items of equipment and elsewhere where considered necessary.

8.3.2 Wherever possible, deck pillars are to fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

8.3.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

8.3.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets or insert plates may be used instead of doublers.

8.3.5 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Holes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

8.4 Pillars in tanks

8.4.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars. The tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 at the tank test pressure. Such pillars are in general to be of built sections and end brackets may be required.

8.5 Fire aspects

8.5.1 Pillars and pillar bulkheads are to be suitably protected against fire, and capable of resisting fire damage. They are not to be constructed of aluminium.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all of the ships detailed in the Rules, and requirements are given for rudders, stabilisers, and appendages, nozzles, steering gear, bow and stern thrust unit structure and waterjet propulsion systems. For podded propulsion systems, *see* Vol 2, Pt 4, Ch 4.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than 0,7σ_u or 450 N/mm^2, whichever is the lesser

where

σ_u = ultimate tensile strength of the material, in N/mm^2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a ship, the requirements of Pt 5, Ch 2,4 are to be complied with.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (Vol 1, Part 2).

1.4.2 Rudder stocks, pintles, coupling flange bolts, keys and cast parts of rudders are assumed to be made of rolled, forged or cast carbon manganese steel in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (Vol 1, Part 2). Where other materials are proposed the scantlings will require to be specially considered on the basis of the Rules.

1.4.3 For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm^2. The following requirements are based on a material's yield stress of 235 N/mm^2. If material is used having a yield stress differing from 235 N/mm^2 the material factor is to be determined as follows:

$$K_o = \left[\frac{\sigma_o}{235}\right]^m$$

where

m = 0,75 for $\sigma_o > 235$ N/mm^2

m = 1,0 for $\sigma_o \leq 235$ N/mm^2

σ_o as defined in 1.2.1.

1.4.4 In order to avoid excessive edge pressures in way of bearings, rudder stock deformations should be kept to a minimum. Where significant reductions in rudder stock diameter due to the application of steels with yield strengths exceeding 235 N/mm^2 are proposed, final acceptance may require the evaluation of the rudder stock deformations.

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by 2.14, 2.15 and 2.16 as appropriate.

2.1.2 For rudders having an increased diameter of rudder stock, *see* Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in radius. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

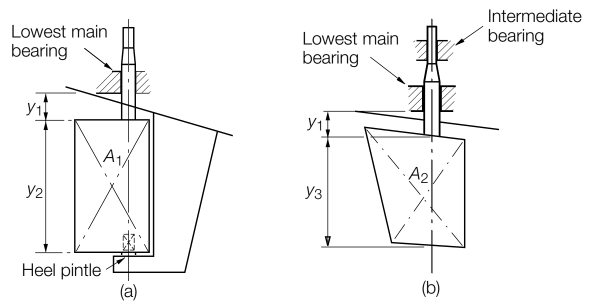


Fig. 3.2.1 Rudder types

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by Lloyd's Register (hereinafter referred to as 'LR').

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for appraisal.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel. Other rudder types and materials will be subject to special consideration.

2.6 Rudder profile coefficient, K_2

2.6.1 The rudder profile coefficient, K_2, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.1.

Table 3.2.1 Rudder profile coefficient, K_2

Design criteria (*see* Fig. 3.2.2)	K_2 ahead condition	K_2 astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
Symbols		
K_2 = rudder profile coefficient for use in 2.11.1		
NOTE Where a rudder is behind a fixed nozzle, the value of K_2 given above, is to be multiplied by 1,3.		

2.7 Rudder angle coefficient, K_3

2.7.1 The rudder angle coefficient, K_3, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.2.

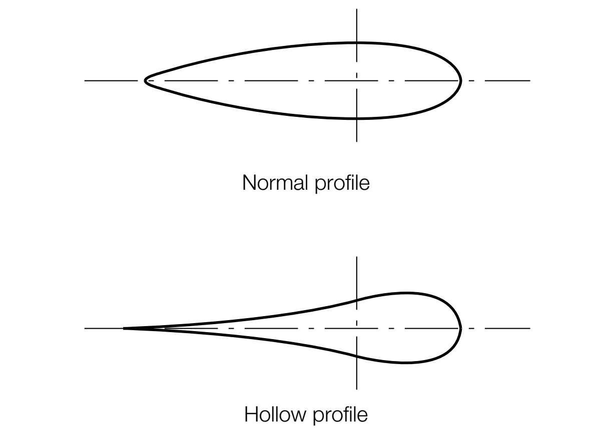


Fig. 3.2.2 Rudder profiles

Table 3.2.2 Rudder angle coefficient, K_3

Rudder angle	2 x 35°	2 x 45°
K_3	1,0	1,23
Symbols		
K_3 = rudder coefficient. Intermediate values may be obtained by interpolation.		

2.8 Rudder position coefficient, K_4

2.8.1 The rudder position coefficient, K_4, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.3.

Table 3.2.3 Rudder position coefficient, K_4

Design criteria		K_4
Ahead condition	Rudder out of propeller slipstream	0,8
	Rudder in propeller slipstream	1,0
	Rudder behind fixed propeller nozzle	1,15
Symbols		
K_4 = rudder position coefficient for use in 2.11.1		

2.9 Rudder speed coefficient, K_5

2.9.1 The rudder speed coefficient, K_5, for use in the determination of rudder force and rudder torque is to be as indicated in Table 3.2.4.

2.10 Centre of pressure

2.10.1 The position of the centre of pressure for use in the determination of the rudder torque is to be as indicated in Table 3.2.5.

Table 3.2.4 Rudder speed coefficient, K_5

Design criteria	K_5
Ships with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$	1,00
Ships with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$	$(1{,}12 - 0{,}005V)^3$
Symbols	
L_R as defined in Ch 1,5.2.2 V as defined in 2.11 K_5 rudder speed coefficient for use in 2.11.1	

2.11 Rudder force, F_R

2.11.1 The rudder force, F_R, for use in the determination of the rudder scantlings is not to be taken less than that determined from the following formula:

$$F_R = 0{,}132 K_1 K_2 K_3 K_4 K_5 A_R V^2 \text{ kN}$$

where

F_R = rudder force, in kN

K_1 = factor depending on the aspect ratio λ of the rudder area

$= \dfrac{(\lambda + 2)}{3}$ with λ is not to be taken greater than 2

$\lambda = \dfrac{h_r^2}{A_R}$, where h_r is mean height of the rudder area, in metres. Mean breadth and mean height of rudder are to be determined from Fig. 3.2.3

A_R = area of rudder blade, in m^2

K_2 = rudder profile coefficient, *see* Table 3.2.1

K_3 = rudder angle coefficient, *see* Table 3.2.2

K_4 = rudder position coefficient, *see* Table 3.2.3

K_5 = rudder speed coefficient, *see* Table 3.2.4

V = maximum design speed for short term high power operations, in knots. When the speed is less than 8 knots, V is to be replaced by the expression:

$$V_{min} = \frac{(V + 16)}{3} \text{ knots}$$

For the astern condition the maximum astern speed, V_A, is to be used. $V_A \geq 0{,}5V$ knots.

2.12 Rudder torque, Q_R

2.12.1 The rudder torque, Q_R, for the ahead condition may be determined from the following formula:

$$Q_R = F_R x_{PF} \text{ kNm}$$

where

F_R = rudder force, in kN

x_{PF} = horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the ahead condition, in metres, *see* Table 3.2.5.

Table 3.2.5 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA}
Rectangular rudders; (a) Ahead condition (b) Astern condition	$x_{PF} = (0{,}33 e_h x_B - x_L)$, but not less than $0{,}12 x_B$ $x_{PA} = (x_A - 0{,}25 x_B)$, but not less than $0{,}12 x_B$
Non-rectangular rudders; (a) Ahead condition (b) Astern condition	x_{PF} and x_{PA} are to be calculated from geometric form (*see* note) but not less than: $\dfrac{0{,}12 A_R}{y_R}$
Symbols	
x_{PF} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres x_{PA} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres x_B = breadth of rudder, in metres y_R = depth of rudder at centreline of stock, in metres A_R = rudder area, in m^2 x_L and x_A = horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres e_h = hull form factor at ahead condition defined as follows: for $L < 65$ m , $e_h = 1{,}0$ for $L \geq 65$ m $e_h = 2\left(C_b + 10\dfrac{B_{WL}}{L_R} - 2\right)\dfrac{V}{\sqrt{L_R}}$ but not less than 1,0 and need not be taken greater than $1 + \left(\dfrac{L_R - 65}{70}\right)$ L_R, B and C_b are as defined in Ch 1,5. V is as defined in 2.11.1	
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) $0{,}33 x_S$ abaft leading edge of strip for ahead condition. (b) $0{,}25 x_S$ from aft edge of strip for astern condition.	

2.12.2 The rudder torque, Q_R, for the astern condition may be determined from the following formula:

$$Q_R = F_R x_{PA} \text{ kNm}$$

where

x_{PA} = horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the astern condition, in metres, *see* Table 3.2.5

F_R = rudder force, in kN

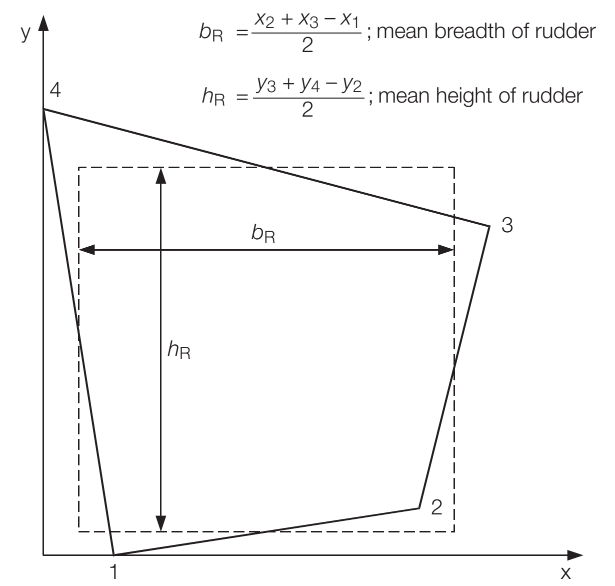


Fig. 3.2.3 Rudder aspect ratio

2.13 Rudder bending moment, M_R

2.13.1 For spade rudders, Type (b) in Fig. 3.2.1 the bending moment, M_R, may be determined from the following formula:

$$M_R = F_R \left(y_1 + \left(\frac{y_3 \, (2x_l + x_u)}{3 \, (x_l + x_u)} \right) \right) \text{ kNm}$$

where

F_R is as given in 2.11.1

y_1, y_3, x_l and x_u are rudder dimensions, in metres *see* Fig. 3.2.4.

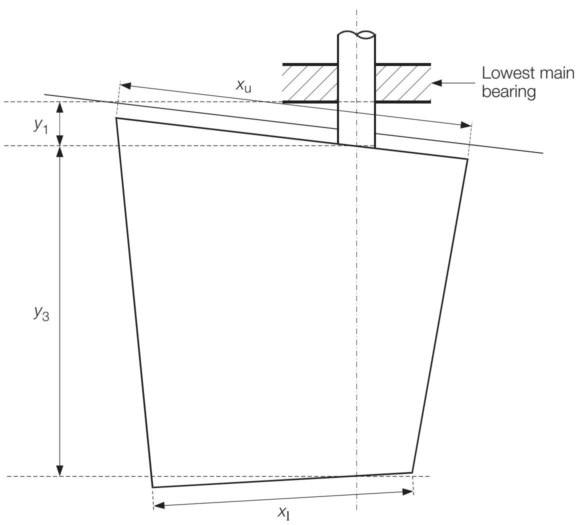


Fig. 3.2.4 Spade rudder

2.13.2 For rudders supported by a rudder horn, Type (a) in Fig. 3.2.1 the bending moment, M_R, may be determined from the following formula:

$$M_R = 0{,}125 F_R \, (y_1 + y_2) \text{ kNm}$$

where

F_R is as given in 2.11.1

y_2 is a rudder dimension, in metres, *see* Fig. 3.2.5.

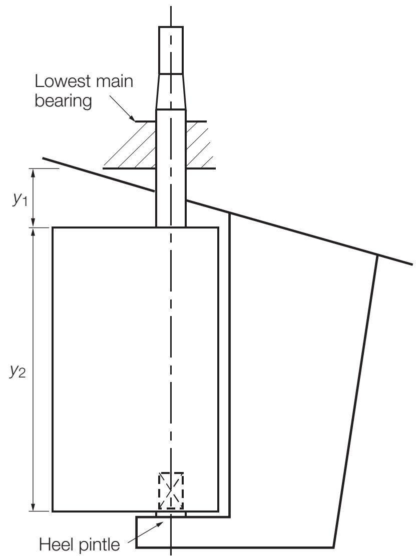


Fig. 3.2.5 Rudder supported by a rudder horn

2.14 Rudder stock diameter in way of the tiller, d_{su}

2.14.1 The torsional stress in the rudder stock, τ_t, in way of the tiller is not to exceed that determined from the following:

$$\tau_t = 68 K_o \text{ N/mm}^2$$

2.14.2 The rudder stock diameter in way of the tiller, d_{su}, is to be not less than that determined from the formula:

$$d_{su} = 42 \sqrt[3]{\frac{Q_R}{K_o}} \text{ mm}$$

where

Q_R = rudder torque (in the appropriate condition), in kNm, as given in 2.12

K_o = material factor, as defined in 1.4.3.

2.15 Rudder stock diameter d_s

2.15.1 For a rudder stock subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed that determined from the following:

$$\sigma_e = 118 K_o \text{ N/mm}^2$$

The equivalent stress is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \text{ N/mm}^2$$

where

Bending stress:

$$\sigma_b = 10200 \frac{M_R}{d_s^3} \times 10^3 \quad N/mm^2$$

Torsional stress:

$$\sigma_t = 5100 \frac{Q_R}{d_s^3} \times 10^3 \quad N/mm^2$$

2.15.2 The basic rudder stock diameter, d_s, at and below the lowest bearing is not to be less than that determined from the following:

$$d_s = d_{su} \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_R}{Q_R}\right)^2} \quad mm$$

where

d_{su} = diameter of the rudder stock in way of the tiller, in mm

M_R = rudder bending moment, kNm, *see* 2.13

Q_R = rudder torque (in the appropriate condition), in kNm, as given in 2.12.

2.16 Rudder stock (tubular)

2.16.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by 2.14.2 and 2.15.2 as appropriate, and can be calculated from the following formula:

$$d_e = \sqrt[3]{\frac{d_1^4 - d_2^4}{d_1}} \quad mm$$

where

d_e = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.17 Single plate rudders

2.17.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.6.

2.17.2 Rudder arms are to be efficiently attached to the mainpiece.

2.18 Double plate rudders

2.18.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.7.

2.18.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.18.3 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

Table 3.2.6 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0{,}0015 V s + 2{,}5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000mm $Z_A = 0{,}0005 V^2 x_a^2 s$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to $0{,}75 d_s$ mm
Symbols	
t_B = blade thickness, in mm s = vertical spacing of rudder arms/stiffeners, in mm V = speed, in knots, as defined in 2.11.1 x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3 d_s = basic stock diameter, given by 2.15.2	

2.18.4 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.19 Cast metal rudders

2.19.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.20 Lowest main bearing requirement

2.20.1 The design of the lowest bearing is to comply with the requirements of Table 3.2.8.

2.21 Bearings

2.21.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.21.2 Synthetic rudder stock bearing materials are to be of a type approved by LR.

2.21.3 Where it is proposed to use stainless steel bearings for rudder stocks, the chemical composition is to be submitted for approval.

2.21.4 When stainless steel bearings are used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

Table 3.2.7 Double plated rudder construction

Item		Requirement
(1) Side plating		$t = 0{,}0224\, s\, \beta \sqrt{\dfrac{P_R}{110 k_o}} + 2{,}5$ mm
(2) Webs – vertical and horizontal		As (1) above
(3) Top and bottom plates		As (1) above using s = maximum rudder width, in mm, at top or bottom, but not less than 900 mm.
(4) Nose plates		$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular		Breadth and width $\geq d_s$ $t_M = (8{,}5 + 0{,}56\sqrt{d_s})$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq 78{,}0$ N/mm^2
(6) Mainpiece – tubular		Inside diameter $\geq d_s$ t_M as for (5) above Side plating as for (1) above Bending stress as for (5) above
(7) Testing	Pressure	2,45 m head and rudder should normally be tested while laid on its side
	Leak (air pressure)	0,02 N/mm^2 and arrangements made to ensure that no pressure in excess of 0,03 N/mm^2 can be applied

Symbols

β = $A_a (1 - 0{,}25A_a)$
A_a = panel aspect ratio, but is not to be taken as greater than 2,0
t = thickness, in mm
s = spacing, in mm, of the webs, arms or stiffeners, but is not to exceed 900 mm
d_s = basic stock diameter, given by 2.15.2, in mm
t_N = thickness, in mm, of nose plate
t_M = thickness, in mm, of side plating and vertical webs forming mainpiece
x_B = breadth of rudder, in metres, on centreline of stock
P_R = rudder pressure
= $10T + \dfrac{F_R}{A_R}$ kN/m^2
T = is as detailed in Ch 1,5.2.9
F_R = rudder force, in kN, given by 2.11
A_R = area of rudder blade, in m^2, given in 2.11.1

2.21.5 When the rudder stock or liner is grade 316*L* austenitic stainless steel, it is recommended that gunmetal, lignum vitae or a synthetic bearing material be used in the bush. If a stainless steel is used in the bush, it is to be of a different grade and with an adequate hardness difference. The use of a ferritic/austenitic duplex structure stainless steel is recommended for the bush, but 17 per cent to 30 per cent chromium stainless steels are also suitable.

2.22 Liners

2.22.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.22.2 Where it is proposed to use stainless steel liners, the chemical composition is to be submitted for approval.

2.22.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

2.23 Pintles

2.23.1 Rudder pintles and their bearings are to comply with the requirements of Table 3.2.9.

2.23.2 Where the lower pintle is housed above the rudder gudgeon, *see* Fig. 3.2.6, C_{PL} is to be measured to the top of the gudgeon.

2.23.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.9.

2.23.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

Table 3.2.8 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1,5d_s \geq Z_B \geq 1,0d_s$	Minimum thickness of wall, in mm lesser of $0,2d_s$ or 100
	Bearing material	Maximum pressure, in N/mm^2 (*see* Note 4)
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Metal Synthetic	7,0 5,5
	Bearing material	Minimum clearance,in mm (*see* Note 3)
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Metal (*see* Note 2) Synthetic	$0,001d_s + 1,0$ $0,002d_s + 1,0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by 2.15.2, in mm		
NOTES 1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered. 2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained. 3. Value of proposed minimum clearance is to be indicated on plans submitted for approval. 4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.		

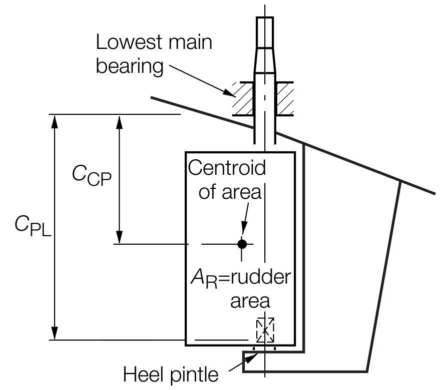


Fig. 3.2.6
Lower pintle housed above rudder gudgeon

2.23.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.23.6 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* 2.40.

2.24 Bolted couplings

2.24.1 Rudder coupling design is to be in accordance with Table 3.2.10.

2.24.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.24.3 For rudders with horizontal couple arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by the non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

2.24.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see* Fig. 3.2.7. The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.24.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 3.2.7(b).

Table 3.2.9 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$d_{PL} = \sqrt{\left(\frac{235}{\sigma_o}\right)^m} \left(31 + 4,17V\sqrt{A_{PL}}\right)$ mm For single pintle rudders $A_{PL} = \frac{A_R\, C_{CP}}{C_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200 mm diameter)	1 in 6
	Manual assembly, key fitted (pintle ≥ 400 mm diameter)	1 in 9
	For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation.	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1,2d_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must be not less than $1,0d_{PL}$ mm	
(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \frac{A_{PL}\, F_R}{A_R}$ kN A_{PL} as for item (1) A_R and F_R are as defined in 2.11.1	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0,5d_{PL}$ but need not normally exceed 125 mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0,001d_{PL} + 1,0$ $0,002d_{PL} + 1,0$ but not less than 1,5

Symbols

d_{PL} = pintle diameter, in mm
V = as defined in 2.11.1 but not less than 10 knots
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions in metres, as indicated in Fig. 3.2.6
A_R = rudder area, in m^2
σ_o = as defined in 1.2.1
Z_{PB} = pintle bearing length, in mm
P_{PL} = force acting on bearing, in kN
b_G = thickness of gudgeon material in way of pintle, in mm
m = as defined in 1.4.3

NOTE
Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

Table 3.2.10 Rudder couplings to stock (*see continuation*)

Arrangement	Parameter	Requirement: Horizontal coupling	Requirement: Vertical coupling
(1) Bolted couplings (*see* Note)	n	≥ 6	≥ 8
	d_b	$\dfrac{0,65 d_s}{\sqrt{n}}$	$\dfrac{0,81 d_s}{\sqrt{n}}$
	m	$0,00071 n\, d_s\, d_b^{\,2}$	$0,00043 d_s^3$
	t_f	$\geq d_b$	d_b
	α_{max} (*see* Note 2)	$(53,82 - 35,29 K_o) - \dfrac{d_s^3}{F_R\, h\, 10^6} - \left(1,8 - 6,3 \dfrac{R}{d_s}\right) \dfrac{t_f - t_{fa}}{t_{fa}}$	–
	$\alpha_{as\ built}$ (*see* Note 2)	$\leq \alpha_{max}$	–
	w_f	$0,67 d_b$	$0,67 d_b$
(2) Conical couplings	θ_t	$\leq \dfrac{1}{K_1}$	
	l_t	$\geq 1,5 d_s$	
	σ_{GM}	$\dfrac{P_R\, \theta_t\, d_{STM} + 4Q_R \sqrt{K_2 \left(\left(\dfrac{P_R\, d_{STM}}{2Q_R}\right)^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2}}{5,66\, (d_{STM})^2\, l_t \left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$	
	w	$\dfrac{9,6 \sigma_{GM}\, d_{STM}}{\theta_t\, (1 - f_m^{\,2})} \times 10^{-6}$	
	P_u	Approximately equal to $2,83\, \sigma_{GM}\, l_t\, d_{STM} \left(K_3 + \dfrac{\theta_t}{2}\right)$	
	P_o	Approximately equal to $2,83 \sigma_{GM}\, l_t\, d_{STM} \left(K_3 - \dfrac{\theta_t}{2}\right)$	
	σ_o	$\geq \dfrac{12,35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{d_{ST}}$	

Table 3.2.10 Rudder couplings to stock (*continued*)

Symbols

n = number of bolts in coupling
d_b = diameter of coupling bolts, in mm
d_s, d_{su} = rudder stock diameters as defined in 2.15 and 2.14 respectively
m = first moment of area of bolts about centre of coupling, in cm^3
t_f = thickness of coupling flange, in mm
w_f = width of flange material outside the bolt holes, in mm
K_o = rudder stock material factor *see* 1.4.3
h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 3.2.7(a)
R = palm radius between rudder stock and connected flange not smaller than $\frac{d_s}{10}$ in mm
t_f = minimum thickness of coupling flange, in mm
t_{fa} = as built flange thickness, in mm
α_{max} = maximum allowable stress concentration factor
$\alpha_{as\ built}$ = stress concentration factor for as built scantlings $= \dfrac{0{,}73}{\sqrt{\left(\dfrac{R}{d_s}\right)}}$
θ_t = taper of conical coupling, on the diameter, e.g.: $\theta_t = \dfrac{1}{15} = 0{,}067$
F_R = rudder force kN
l_t = length of taper, in mm

σ_{GM} = required mean grip stress, in N/mm^2
w = corresponding push-up of rudder stock, in mm
P_u, P_o = corresponding push-up, pull-off loads respectively, in N
σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength
P_R = effective weight of rudder, in N
d_{STM} = mean diameter of coupling taper, in mm
d_{ST} = diameter of coupling taper at any position, in mm
d_{GHM} = mean external diameter of gudgeon housing, in mm
d_{GH} = external diameter of gudgeon housing at any position, in mm
$f_m = \dfrac{d_{STM}}{d_{GHM}}$
$f = \dfrac{d_{ST}}{d_{GH}}$
Q_R = maximum turning moment applied to stock, and is to be taken as the greater of:
(a) As determined from 2.12.
(b) The torque generated by the steering gear at the maximum working pressure

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

NOTES
1. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.
2. For spade rudders with horizontal coupling, t_f is not to be less than $0{,}25d_s$.
3. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 3.2.7.

2.25 Conical couplings

2.25.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked and the push-up then measured from that point. The upper edge of the upper main-piece bore is to have a slight radius. After final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.25.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.26 Rudder carrier arrangements

2.26.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.27 Anti-jump collars

2.27.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.27.2 Jumping collars are not to be welded to the rudder stock.

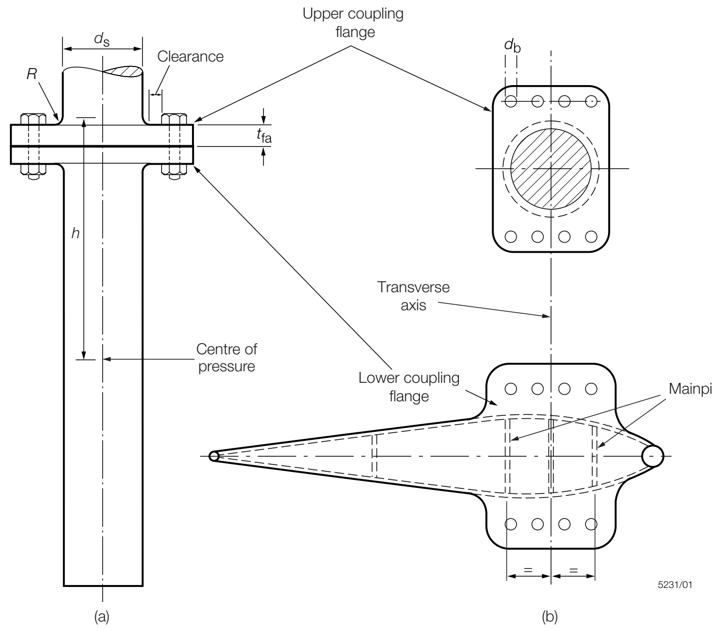


Fig. 3.2.7 Rudder stock connection

2.28 Drain plugs

2.28.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

2.29 Corrosion protection

2.29.1 All metalwork is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.29.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means is to be employed for this purpose.

2.30 Dissimilar materials

2.30.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see* 2.15.

2.31 Internal coatings

2.31.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted for consideration.

2.32 Pressure testing

2.32.1 For testing of rudders, *see* Part 6.

2.33 Tiller arms, quadrants

2.33.1 Tillers and quadrants are to comply with the requirements of Vol 2, Pt 6, Ch 1.

2.33.2 The steering gear is to be mounted on a seat and adequately secured.

2.34 Connecting bars

2.34.1 Connecting bars are to comply with the requirements of Vol 2, Pt 6, Ch 1.

2.35 Keys and keyways

2.35.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0{,}25 d_{su}$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{su}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{su} is as defined in 2.14.

2.35.2 Keyways are to extend over the full depth of the tiller boss.

2.35.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.36 Stopping arrangements

2.36.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.37 Novel designs

2.37.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the calculations are to be submitted for consideration.

2.38 Rudder tube arrangements

2.38.1 The rudder tube construction is to be of steel.

2.38.2 The scantlings of rudder tubes will be individually considered.

2.38.3 The bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.38.4 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.38.5 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.38.6 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.38.7 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

2.39 Watertight gland

2.39.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.39.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as 'O' rings may be accepted.

2.39.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube; the gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.39.4 Alternative arrangements utilising lip seals or 'O' rings either in isolation or in combination with one or other of the alternative seal arrangements will be the subject of special consideration.

2.40 In-water Survey requirements

2.40.1 Where in-water surveys are required, notation is to be assigned, (*see* Pt 1, Ch 2,4.5.5), means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the ship afloat.

■ *Section 3*
Stabiliser arrangements

3.1 General

3.1.1 This section details the requirements for fin stabilisers, stabiliser tanks and bilge keel and fins.

3.1.2 The effectiveness of the fin stabilisers are out with the scope of classification; however their scantlings, arrangements, foundations, supporting structure and watertight integrity are to be examined.

3.1.3 Engineering systems are to comply with the appropriate requirements indicated in Volume 2, as applicable.

3.1.4 The general structure of the fin stabiliser is to comply with the Rule requirements for rudders.

3.1.5 Fin stabilisers are to be contained between watertight bulkheads.

3.1.6 For non-retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than one third of the root chord length, *C*, from the fore and aft most extents of the stabiliser, *see* Fig. 3.3.1. This requirement exists in order to ensure limited flooding in the event of hull damage in way of the fin. Alternate arrangements which are considered to be equivalent to the Rule requirements will be accepted.

3.1.7 For retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than the total length of the stabiliser (measured from the extreme end of the shaft to the blade tip) from the centreline of the stabiliser shaft.

3.1.8 For non-retractable type stabilisers, a separate watertight box surrounding the shell entry point may be required if the stabiliser is located adjacent to a critical compartment. No stabiliser box is needed if the compartment which it is in has adequate pumping arrangements and the ship has at least a one compartment flooded damage capability.

3.1.9 Where a watertight box surrounding the shell entry point is required, it is to extend longitudinally not less than the minimum bulkhead positions defined in 3.1.6 and vertically to ensure complete enclosure of the machinery and allow adequate inspection, *see* Fig. 3.3.1.

3.1.10 For both retractable and non-retractable type stabilisers the compartment in which the stabilisers are fitted is to contain a water ingress detector and alarm.

3.1.11 Fin stabiliser systems are, in general, not to extend beyond the extreme waterline breadth, B_{WL}, of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the fore and aft extent of the stabiliser, when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

3.1.12 The shell plating in way of retractable stabilisers is to comply with the requirements of 3.2. However, the longitudinal extent of the insert is to be such that it extends beyond around the hull opening in the fore/aft direction by not less than 25 per cent of the root chord length of the foil. In all other directions the extent of the insert shall be 1,25 times the root chord length of the foil over all operational lengths.

3.1.13 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be specified by the designer/builder and/or fin unit manufacturer, but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3. Suitable access is to be provided to allow for maintenance and inspection purposes.

3.1.14 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element analysis, if carried out.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from the high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the ship.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile shear strength values (N/mm^2).

3.1.15 Fin bearing materials are to be of an approved type.

3.1.16 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and at auxiliary steering positions.

3.1.17 Where the fin stabiliser is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots, and the anticipated loads are likely to be significant, the scantlings of the fin and fin stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

3.2 Fin stabilisers

3.2.1 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where cyclic bending stresses are induced in the structure which are likely to reduce the fatigue life the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered.

3.2.2 The fin box into which the stabilisers are fitted is to have a perimeter plating with thickness not less than the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the adjacent hull structure. Ships constructed from materials other than steel will be specially considered.

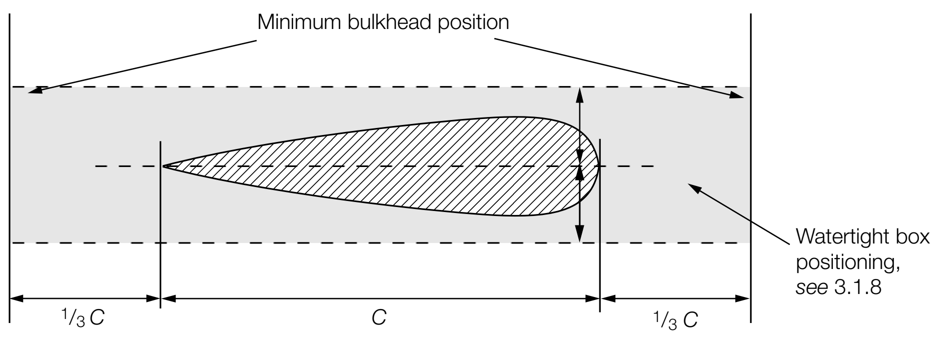


Fig. 3.3.1 Stabiliser positioning

3.2.3 Insert plates are to be fitted in way of stabilisers. The thickness of the insert is to be at least 50 per cent greater than the bottom shell thickness in way and is to extend over an area 1,25 times the stabiliser root chord length, covering all operational angles. In addition, for retractable stabilisers, the insert is to extend beyond the shell opening for a distance of not less than 25 per cent of the length of the root chord.

3.2.4 The thickness of plating in way of retractable foil recesses is to be not less than the bottom shell thickness plus 2 mm. Internal stiffening is to comply with the requirements of Ch 3,4, as applicable.

3.3 Centre of pressure

3.3.1 The position of the centre of pressure for use in the determination of the fin torque is to be as indicated in Table 3.3.1.

3.4 Fin force, F_F

3.4.1 The fin force, F_F , in kN, for use in the determination of the fin scantlings is to be submitted. For the astern condition the maximum astern speed, V_A, is to be used. In no case is the astern speed to be taken less than that determined from the following: $V_A \geq 0,5V$ knots.

3.5 Fin torque, Q_F

3.5.1 The fin torque, Q_F, for the ahead condition may be determined from the following formula:

$$Q_F = F_F\, x_{PF} \quad \text{kNm}$$

where

x_{PF} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition, in metres, *see* Table 3.3.1

F_F = fin force as defined in 3.4.1.

3.5.2 The fin torque, Q_F, for the astern condition may be determined from the following formula:

$$Q_F = F_F\, x_{PA} \quad \text{kNm}$$

where

x_{PA} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the astern condition, in metres, *see* Table 3.3.1

F_F = fin force as defined in 3.4.1.

3.6 Fin bending moment, M_F

3.6.1 For conventional fins the bending moment, M_F, may be determined from the following formula:

$$M_F = F_F\left(y_1 + \left(\frac{y_2\,(2x_l + x_u)}{3\,(x_l + x_u)}\right)\right) \quad \text{kNm}$$

where

F_F is as given in 3,4

y_1, y_3, x_l and x_u are fin dimensions, in metres *see* Fig. 3.3.2

Table 3.3.1 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA}
Rectangular fins; (a) Ahead condition (b) Astern condition	 x_{PF} = $(0,33x_B - x_L)$, but not less than $0,12x_B$ x_{PA} = $(x_A - 0,25x_B)$, but not less than $0,12x_B$
Non-rectangular fins; (a) Ahead condition (b) Astern condition	 x_{PF} as calculated from geometric form x_{PA} (*see* note) but not less than: $\dfrac{0,12A_F}{y_F}$

Symbols

x_{PF} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition, in metres

x_{PA} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the astern condition, in metres

x_B = breadth of fin, in metres

y_F = depth of fin at centreline of stock, in metres

A_F = fin area, in m^2

x_L and x_A = horizontal distances from leading and after edges, respectively, of the fin to the centreline of the fin stock, in metres

x_S = horizontal length of any rectangular strip of fin geometric form, in metres

L_R, B and C_b are as defined in Ch 1,5.2

V is as defined in 2.11.1

NOTE

For rectangular strips the centre of pressure is to be assumed to be located as follows:

(a) $0,33x_S$ abaft leading edge of strip for ahead condition.

(b) $0,25x_S$ from aft edge of strip for astern condition.

3.7 Fin stock diameter in way of tiller, d_{Fu}

3.7.1 The fin stock diameter in way of the tiller, d_{Fu}, is to be not less than that determined from the formula:

$$d_{Fu} = 42\sqrt[3]{\frac{Q_F}{K_o}} \quad \text{mm}$$

where

Q_F = fin torque (in the appropriate condition), in kNm, as given in 3,5

K_o = material factor, as defined in 1.4.3.

3.8 Fin stock diameter, d_F

3.8.1 For a fin stock subjected to combined torque and bending, the equivalent stress in the fin stock is not to exceed that determined from the following:

$$\sigma_e \leq 118K_o \text{ N/mm}^2$$

where

K_o = material factor, as defined in 1.4.3.

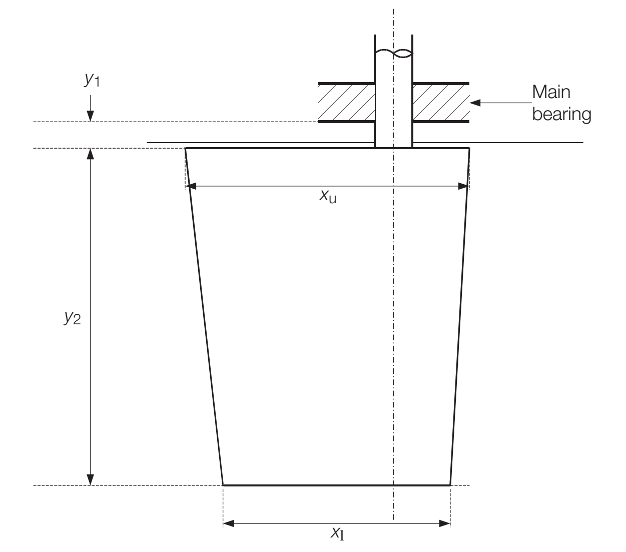


Fig. 3.3.2 Fin stabiliser

The equivalent stress is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2} \quad \text{N/mm}^2$$

Bending stress: $\sigma_b = 10200 \dfrac{M_F}{d_F^3} \times 10^3$ N/mm^2

Torsional stress: $\tau_t = 5100 \dfrac{Q_R}{d_F^3} \times 10^3$ N/mm^2

3.8.2 The basic fin stock diameter, d_F, at and below the lowest bearing is not to be less than that determined from the following:

$$d_F = d_{Fu} \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_F}{Q_F}\right)^2} \quad \text{mm}$$

where

d_{Fu} = diameter of the fin stock in way of the tiller, in mm
M_F = fin bending moment, kNm, *see* 3,6
Q_F = fin torque (in the appropriate condition), in kNm, as given in 3,5.

3.9 Fin plating

3.9.1 The thickness of the fin side plating is not to be less than that determined from the following:

$$t = 0{,}0224\, s\, \beta \sqrt{\frac{P_F}{110 K_o}} + 2{,}5 \quad \text{mm}$$

where

s = stiffener spacing, in mm
β = panel aspect ratio correction factor
= A_R (1 – 0,25A_R) for $A_R \leq 2$
= 1 for A_R>2
A_R = panel aspect ratio
= panel length/panel breadth
P_F = fin pressure, in kN/m^2
= $10T + \dfrac{F_F}{A_F}$ kN/mm^2
T = maximum draught, in metres
F_F = fin force, in kN, *see* 3,4
A_F = fin area, in m2
K_o = material factor, as defined in 1.4.3.

3.9.2 The thickness of the nose plates is not to be less than 1,25 times the thickness of the fin side plating. The thickness of web plates is not to be less than 70 per cent the thickness of the fin side plating, or 6 mm whichever is the greater.

3.9.3 Alternative materials and methods for fin stabilisers will be specially considered.

3.10 Stabiliser tanks

3.10.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

3.11 Bilge keels and fins

3.11.1 It is recommended that bilge keels are not fitted forward of 0,7L_R on ships intended to navigate in ice conditions.

3.11.2 Bilge keels are to be gradually tapered at the ends and arranged to finish in way of a suitable internal stiffening member. The taper is to have a length to depth ratio of at least three to one.

3.11.3 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

3.11.4 The scantlings and attachment to the hull plating for steel ships is to be in accordance with Pt 6, Ch 6,5.9.

3.12 Novel features

3.12.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4*
Rudder horns and appendages

4.1 General

4.1.1 Rudder horns and boss end brackets may be constructed of cast or forged steel or fabricated from steel plate. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel.

4.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

4.1.3 Castings and forgings are to comply with the requirements of Pt 2, Ch 4 and Ch 5.

4.1.4 Rudder horns, shaft brackets, etc., are to be effectively integrated into the ship structure, and their design is to be such as to facilitate this.

4.2 Propeller boss

4.2.1 The thickness of the propeller boss is to be not less than:

$0{,}1d_{TS} + 56$ but need not exceed $0{,}3d_{TS}$

where

d_{TS} = diameter of tailshaft in mm, *see* Fig. 3.4.1.

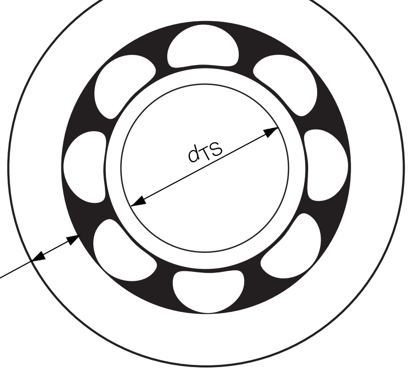


Fig 3.4.1 Propeller boss

4.3 Rudder horns

4.3.1 The requirements for the scantlings and arrangements of rudder horns will be subject to special consideration and may require to be determined by direct calculations.

4.4 Shaft bossing

4.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the ship's internal structure.

4.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

4.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the ship. The arms are to be strengthened at intervals by webs.

4.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.4.5 The scantlings of supports will be specially considered. In the case of certain high powered ships, direct calculations may be required.

4.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

4.5 Shaft brackets

4.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 4.6.1 or 4.7.2 as appropriate.

4.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small ships the use of single arm brackets will be considered.

4.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.5.4 Bracket arms are in general to be carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

4.5.5 In the case of certain high powered ships direct calculations may be required.

4.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 4.5.1.

4.5.7 Where the shaft and the shaft bracket boss are of the same material, the length and thickness of the shaft bracket boss are to be not less than $4d_t$ and $d_t/4$, respectively, where d_t is the Rule diameter of the screwshaft, in mm.

4.5.8 Where the shaft and the shaft bracket boss are of dissimilar materials, the length of the boss is to be not less than $4d_t$, and the thickness, t_b, of the boss is to be not less than:

$$t_b = 0{,}75 d_t \left(\sqrt[3]{f_1} - 0{,}667\right) \text{ mm}$$

NOTE
In no case is t_b to be taken as less than 12 mm.

where
- d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm
- f_1 = σ_S/σ_B but not less than 0,825
- σ_S = ultimate tensile strength of the shaft material, in N/mm^2
- σ_B = ultimate tensile strength of the boss material, in N/mm^2

4.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is out with the scope of classification.

4.6 Single arm shaft brackets ('P' – brackets)

4.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s\, d_{ms}^2\, f}{45000} \text{ cm}^3$$

where
- a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see* Fig. 3.4.2
- d_{ms} = the Rule diameter for an unprotected screwshaft, in mm, as given in Vol 2, Pt 3, Ch 2 using
- A = 1,0
- f = $400/\sigma_u$
- σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

4.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

4.7 Double arm shaft brackets ('A' – brackets)

4.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

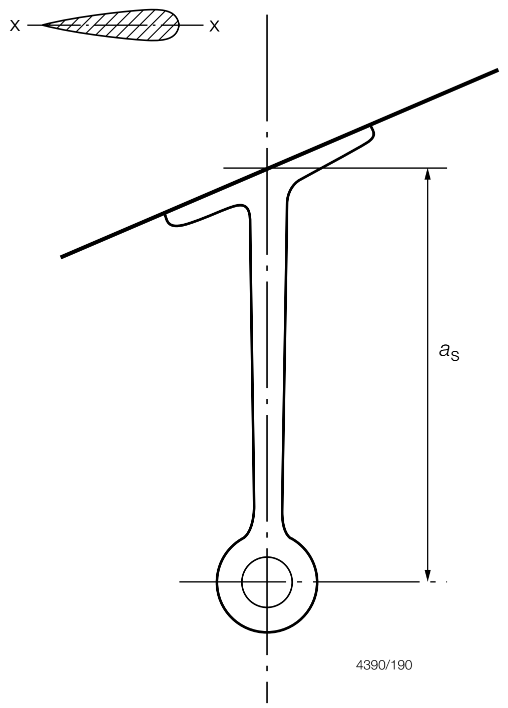


Fig 3.4.2
Single arm shaft bracket (bolted attachment)

4.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0{,}45\, n^3 \text{ cm}^3$$

where
- n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_{ms} \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_{ms}}\right)^2\right)}\right)} \text{ cm}$$

- a_d = the length of the longer strut, in mm, *see* Fig. 3.4.3

d_{ms} and f are as given in 4.6.1.

4.8 Intermediate shaft brackets

4.8.1 The length and thickness of the shaft bracket boss are to be as required by 4.5.7 or 4.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

4.9 Attachment of shaft brackets by welding

4.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

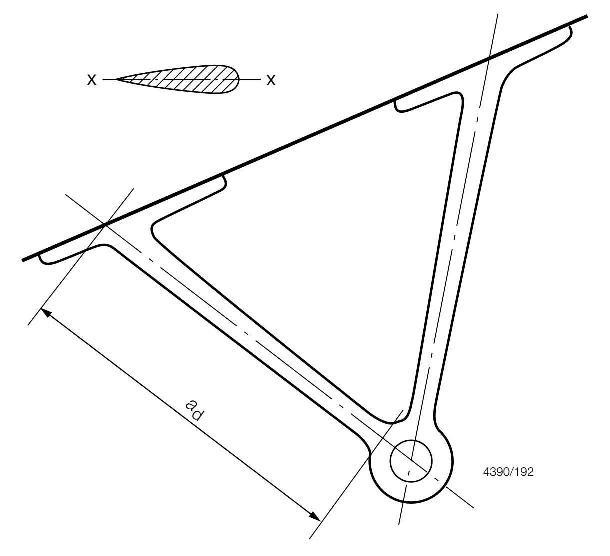


Fig. 3.4.3
Double arm shaft bracket (bolted attachment)

4.10 Attachment of shaft brackets by bolting

4.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates are to be additionally supported by substantial floor plates or other structure.

4.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

4.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

4.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

4.10.5 The minimum thickness of a resin chock is to be 12 mm.

4.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 4.5.7 or 4.5.8 as appropriate.

4.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8,75\,\pi\, n\, h \times 10^{-5}}} \text{ mm}$$

subject to $d_{bmin} \geq t_b$ mm
where

Z_{xx} = the section modulus of the bracket arm determined from 4.6.1 or 4.7.2, cm^3, as appropriate
n = the number of bolts in each row
h = the distance between rows of bolts, mm
d_b = the bolt diameter in the same material as the propeller bracket, mm
t_b = the propeller bracket boss thickness, mm.

4.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 4.10.7, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

4.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

4.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness t_b/6 mm, subject to a minimum of 3 mm.

4.11 Alignment of shaft brackets

4.11.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

4.11.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type, *see* 4.10.2 and 4.10.3.

4.11.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

4.12 Sterntubes

4.12.1 The sterntube scantlings are to be individually considered.

4.12.2 The bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

4.12.3 The sterntube should in general be connected to the shell by welding. Bolted arrangements will be specially considered.

4.12.4 Where sterntubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

4.12.5 Where stern tubes are to be welded to hull insert plates full penetration welding is required.

4.12.6 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 6, Ch 6 are to be complied with.

4.12.7 The region where the shafting enters the ship, and the bearing in way, is to be adequately supported by floors or deep webs.

4.12.8 The shaft bearings are to be secured against rotation within the sterntube.

4.12.9 A suitable gland arrangement is to be provided at the inboard end of sterntubes.

4.13 Skegs

4.13.1 Skegs are to be efficiently integrated into the adjacent hull structure and their design is to facilitate this.

4.13.2 The scantlings of skegs are to be sufficient to withstand any docking forces imposed upon them.

4.14 Propeller hull clearances

4.14.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.4.1. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Table 3.4.1 Recommended minimum propeller hull clearances

Number of of blades	Hull clearances for twin screw, in metres, *see* Fig. 3.4.4	
	e	*f*
3	$1{,}20K\,d_P$	$1{,}20K\,d_P$
4	$1{,}00K\,d_P$	$1{,}20K\,d_P$
5	$0{,}85K\,d_P$	$0{,}85K\,d_P$
6	$0{,}75K\,d_P$	$0{,}75K\,d_P$
Minimum value	3 and 4 blades, $0{,}20d_P$ 5 and 6 blades, $0{,}16d_P$	$0{,}15d$

Symbols

L_R and C_B as defined in Ch 1,5.2

$$K = \left(0{,}1 + \frac{L_R}{3050}\right)\left(\frac{3{,}48C_B P_s}{L_R{}^2} + 0{,}3\right)$$

t_R = thickness of rudder, in metres measured at $0{,}7R_p$ above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

d_P = propeller diameter, in metres

NOTE

The above recommended minimum clearances also apply to semi-spade type rudders.

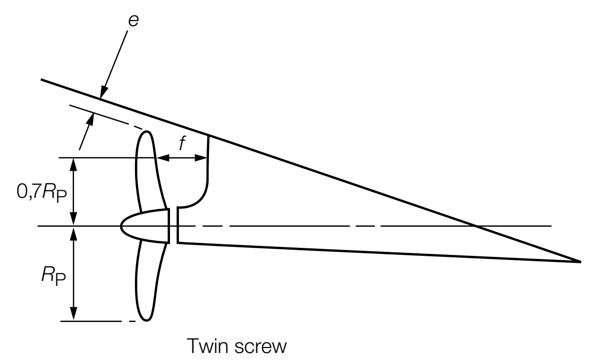


Fig 3.4.4 Propeller clearance

■ *Section 5* Fixed and steering nozzles, bow and stern thrust units, ducted propellers

5.1 General

5.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 5.2 to 5.4 and Table 3.5.1.

5.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 3.5.1. Nozzles exceeding this value will be specially considered.

5.2 Nozzle structure

5.2.1 For basic scantlings of the structure, *see* Table 3.5.1, in association with Fig. 3.5.1.

5.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

5.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 3.5.1.

5.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.5.1, the increased thickness is to be maintained to the adjacent fore and aft web.

5.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

5.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

5.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* Part 6.

Table 3.5.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01 P\, d_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1 N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052 N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8 mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 Torsional stress in upper stock $\leq 62{,}0$ N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2
Symbols	
N_N = a numeral dependent on the nozzle requirements P = power transmitted to the propellers, in kW d_P = diameter of the propeller, in metres t_S = thickness of shroud plating in way of propeller tips, in mm t_p = thickness of plating, in mm t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm	
NOTE Thicknesses given are for carbon steel. Reductions in thickness will be considered for certain stainless steels.	

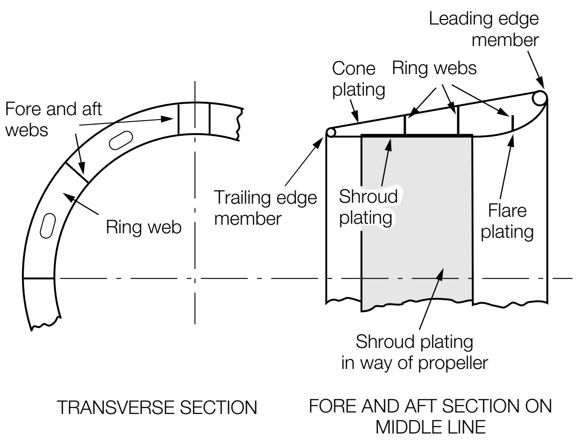


Fig. 3.5.1 Fixed and steering nozzles

5.3 Nozzle stock and solepiece

5.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.5.1, in both the ahead and astern conditions.

5.4 Ancillary items

5.4.1 The diameter of pintles and the diameter and first moment of area about the stock axis of coupling bolts are to be derived from 2.23 and 2.24 respectively.

5.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

5.5 Steering gear and allied systems

5.5.1 For the requirements of steering gear, *see* Vol 2, Pt 6, Ch 1.

5.6 Thruster unit wall thickness

5.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.

5.7 Thruster unit installation details

5.7.1 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

5.7.2 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

5.7.3 For welded tube connections the welding is to be by full penetration welding.

5.7.4 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

5.7.5 The unit is to be adequately supported and stiffened.

5.8 Propeller ducting

5.8.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

5.8.2 The tunnel wall in way of the propeller blades is to be additionally stiffened

5.9 Surface drive mountings

5.9.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

5.9.2 The thickness of transom plating in way is to be increased by 50 per cent or as advised by the drive manufacturer, whichever is the greater.

5.9.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

5.10 Novel features

5.10.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 6* Waterjet propulsion systems

6.1 Construction

6.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

6.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate.

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

6.1.3 When submitting the plans requested in 6.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

6.1.4 All materials used in construction are to be manufactured and tested in accordance with the Rules for Materials (Vol 1, Part 2).

6.1.5 Steels are to be of suitable grades in accordance with the requirements of Pt 6, Ch 6.

6.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

6.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

6.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

6.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

6.1.10 For details of machinery requirements, *see* Vol 2, Pt 4, Ch 2.

6.2 Water jet propulsion systems – Installation

6.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 6.1.4.

6.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 6.1.

6.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

6.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

6.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

6.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

6.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

6.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

6.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

6.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

■ *Section 1* Introduction

1.1 General

1.1.1 The requirements of this Chapter are applicable to all ship types. If required, reference should be made to any additional or alternative standards that are specified by the Naval Authority which will also be considered. Details are to be submitted.

1.1.2 The requirements of this Chapter are applicable to all openings on the weather deck. Openings on the tops and sides of enclosed structures on the weather deck up to a height of 2,5 m are to be weathertight. In the forward 0,25L_R the height should be taken to 5 m. The height of openings may be required to be increased where this is shown necessary by the stability and watertight subdivision calculation required by Pt 1, Ch 1,1.1. The weather deck as defined in Pt 3, Ch 1,5.4.2 may be stepped or recessed for the purpose of this Chapter. Special consideration will be given to the position of the weather deck of NS1 ship types.

1.1.3 Provisions covering acceptable arrangements for the watertight and weathertight integrity of the hull and spaces within the hull are to be read in conjunction with the limits defined in Pt 3, Ch 1,1.3.

1.1.4 Requirements are given for steel hatches, securing arrangements, coamings, also closing arrangements for other miscellaneous openings, ventilators, air pipes, magazine blow-out plates, discharges and outfit. For side shell doors for main opening and bow doors, *see* Pt 4, Ch 3.

1.1.5 A boundary or a closing appliance is considered weathertight if it is capable of preventing the passage of water into the ship in any sea condition. Weathertightness can be obtained, by design, where closing arrangements are constructed of steel (or equivalent) and are capable of being closed by clamping devices or bolts. The joining parts are to be gasketed and for all practical purposes have an equivalent structural integrity and tightness to the surrounding structure.

1.1.6 The requirements for closing appliances in this Chapter are suitable for weathertight arrangements. When closing appliances are designed to comply with the requirements for NBC Defence, they will be considered as being equivalent to the weathertight requirements of this Chapter.

■ *Section 2* Hatches and miscellaneous openings on the weather deck

2.1 Hatch covers

2.1.1 The hatch covers on the weather decks of all ships are to be steel plated, stiffened by webs or stiffeners, hinged and secured by clamping devices. Weathertightness to be achieved by means of gaskets. The means of securing are to be such that weathertightness can be maintained in any sea condition. Where toggles are fitted, their diameter and spacing are to be in accordance with ISO standards or equivalent.

2.1.2 Weathertight or gastight hatches (NBCD) should be located on lower decks in accordance with requirements as specified by the Naval Authority, *see* Pt 4, Ch 1.

2.1.3 The scantlings of covers are not to be less than the rule thickness for the deck at that point. Where other materials are used, equivalent scantlings are to be provided. The scantlings apply basically to rectangular covers, with the stiffening members arranged primarily in one direction and carrying a uniformly distributed load. The covers are assumed to be simply supported. Where covers are stiffened by a grillage formation, and also where point loads are applied to any type of cover, the scantlings are to be determined from direct calculations.

2.1.4 In the case of flush hatch covers or of covers on coamings of lesser height than required by 2.3.1, their scantlings, the securing and sealing arrangements and the drainage of gutterways will be specially considered.

2.1.5 Where hatchways are trunked through one or more lower decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened. Plans are to be submitted for approval.

2.1.6 Small hatches, including escape hatches are to be situated clear of RAS stores receiving areas and storing routes.

2.1.7 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck or the surrounding structure is suitably compensated. Portable plates are to be secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

2.2 Hatch coamings

2.2.1 The height of coamings above the upper surface of the weather deck, measured above sheathing if fitted, is to be not less than 300 mm. For exposed decks immediately above the design draft, e.g. quarter decks and well decks, coaming heights are to be no less than 600 mm. Coaming of a height no less than 450 mm may be provided if the hatch cover is kept closed and a small access hatch is provided in the hatch cover.

2.2.2 The height of coamings of hatchways closed by steel covers fitted with gaskets and clamping devices are to be as specified in 2.2.1, but may be reduced, or the coamings may be omitted entirely, if the safety of the ship is not thereby impaired in any sea condition. Special attention will be given in such cases to the scantlings of the covers, to their gasketing and securing arrangements and to the drainage of recesses in the deck.

2.2.3 The height of coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Pt 3, Ch 2,1.2.

2.2.4 Vertical coamings are to have a thickness, t, in mm not less than the greater of the following:
(a) $t = 0{,}008H_{c}\sqrt{k} + 1{,}0$ mm
(b) Rule thickness of the deck in the position fitted
where
H_c = the coaming height
k = local strength steel factor, *see* Pt 6, Ch 5.

2.2.5 Vertical coamings are to be stiffened at their upper edge by a substantial rolled or fabricated section. Additional support is to be arranged as necessary.

2.3 Manholes and flush escape hatches

2.3.1 Manholes are to be closed by substantial covers capable of being made watertight. The covers are to be permanently attached.

2.3.2 Flush escape hatches are to be closed by substantial weathertight covers capable of being opened and closed from either side except to high security areas such as magazines. The covers are to be permanently attached.

2.4 Hatchways within enclosed superstructures or lower decks

2.4.1 The requirements of this section are to be complied with where it is necessary to maintain the weathertight envelope.

2.4.2 Access hatches within a superstructure or deckhouse need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

2.5 Magazine blow out plates

2.5.1 Where blow out plates are required they are to be secured by sealing arrangements adequate to meet the weathertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

2.5.2 Blow out plates are to be permanently attached.

■ *Section 3* Doors and accesses on weather decks

3.1 General

3.1.1 Access openings in:
(a) superstructure bulkheads;
(b) deckhouses protecting openings leading into enclosed superstructures or to spaces below the weather deck; and
(c) deckhouse on a deckhouse protecting an opening leading to a space below the weather deck,

are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 3.1.3 and 3.1.4.

3.1.2 Fixed lights in doors are to comply with the requirements for side scuttles lights as given in 5.1. Hinged steel deadlights may be external.

3.1.3 The height of doorway sills above the weather deck sheathing, if fitted, is to be not less than 300 mm.

3.1.4 For exposed decks immediately above the design draught, e.g. quarter decks and well decks, sill heights are to be no less than 450 mm.

3.1.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 3.1.1, interior deck openings are to be treated as if exposed on the weather deck.

3.1.6 The height of door sills may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Ch 2,1.2.

3.1.7 Where portable plates are required for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

3.1.8 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

3.1.9 Special consideration will be given to access on the weatherdeck where for operational purposes it is not possible to provide a sill meeting 3.1.3 or 3.1.4.

3.2 Magazine blow out plates

3.2.1 Where blow out plates are required, they are to be secured by sealing arrangements adequate to meet the weathertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

3.2.2 Blow out plates are to be permanently attached.

■ *Section 4* Side lights and windows

4.1 General

4.1.1 A plan showing the location of side lights and windows is to be submitted.

4.1.2 Side lights and windows together with their glasses and deadlights if fitted, are to be of an approved design or in accordance with recognised Naval Authority requirements.

4.1.3 Side lights to spaces within enclosed superstructures, or deckhouses on or above the weather deck are to be fitted with efficient, hinged, inside deadlights and capable of being effectively closed and secured watertight.

4.1.4 All side lights are to be of the non-opening type.

4.1.5 Windows should not generally be fitted in end bulkheads of superstructures.

4.1.6 If fitted in a deckhouse or superstructures in the forward $0,25L_R$, windows are to be provided with strong, hinged, steel, weathertight storm covers. However, if there is an opening leading below deck, this opening is to be treated as being on an exposed deck and is to be protected as required by 2.2.1.

4.1.7 Side lights and windows set inboard from the shell on the weather deck, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external steel storm covers instead of internal deadlights.

4.1.8 Side lights and windows set inboard from the shell on the weather deck, not protecting direct access below, do not require deadlights or storm covers.

4.1.9 Cabin bulkheads and doors are considered to provide effective protection between side lights or windows and access below.

4.1.10 Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0,25L_R$, strong external storm covers which may be portable and stored adjacent are to be provided.

4.1.11 Where the bridge is on, or not more than 5,0 m above, the weather deck in lieu of storm covers being provided for the bridge windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the bridge, may be accepted. If this arrangement is accepted, adequate means of draining the bridge are to be provided.

4.1.12 If necessary, for practical considerations, the storm covers may be in two parts.

4.1.13 Laminated toughened safety glass may also be used for windows but the total thickness will need to be greater than that required for the equivalent sized window using toughened safety glass. The equivalent thickness of laminated toughened safety glass is to be determined from the following formula:

$$T_{L1}^2 + T_{L2}^2 + ...T_{Ln}^2 = T_S^2$$

where
- n = number of laminates
- T_L = thickness of glass laminate
- T_S = thickness of toughened safety glass.

4.1.14 Rubber frames are not acceptable for windows.

Section 5
Ventilators

5.1 Application

5.1.1 This Section applies to all ship types and provides requirements for ventilators. Reference should be made to any additional or alternative standards that are specified by the Naval Authority which will also be considered. Details are to be submitted.

5.1.2 For requirements regarding down flooding in connection with stability and watertight subdivision, *see* Ch 2,1.3.

5.2 Protection

5.2.1 In all spaces where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

5.3 General

5.3.1 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

5.3.2 Ventilators from tunnels passing through decks are to have scantlings suitable for withstanding the pressures to which they may be subjected and are to be made watertight.

5.4 Coamings

5.4.1 The scantlings and height of ventilator coamings exposed to the weather are to be not less than required by Table 4.5.1 but the thickness need not exceed that of the adjacent deck or bulkhead plating. In particularly exposed positions, the height of coamings and scantlings may be required to be increased.

5.4.2 The height of ventilator coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Pt 1, Ch 1,1.1. The Naval Authority may require that the height of all ventilator coamings are above the θ_{df} angle, *see* Ch 1,1.2.

5.4.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

5.4.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

Table 4.5.1 Ventilator coaming requirements

Feature	Requirements
Height (measured above sheathing if fitted)	(1) z_c = 900 mm for locations defined in Note 2 z_c = 760 mm elsewhere
Thickness	(2) t_c = 5,5 + 0,01 d_v mm where 7,5 mm ≤ t_c ≤ 10,0 mm
Support	(3) If z_c > 900 mm the coaming is to be specially supported
Symbols	
t_c = thickness of coaming, in mm z_c = height of coaming, in mm d_v = internal diameter of coaming, in mm	

NOTES
(1) Where the height of the ventilator exceeds that given in Item (1), the thickness given by (2) may be gradually reduced, above that height, to a minimum of 6,5 mm. The ventilator is to be adequately stayed.
(2) For exposed decks immediately above the design waterline, e.g. quarter decks and well decks.

5.4.5 Ventilator coaming heights may be reduced on ships assigned a service area notation **SA4**. Coaming heights are to be as high as practicable, with a minimum height of 300 mm.

5.5 Closing appliances

5.5.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless the height of the coaming is greater than 2,5 m above the weather deck or 5 m on exposed deck immediately above the design waterline, e.g. quarter decks and well decks.

5.5.2 Where ventilators are proposed to be led overboard through an enclosed lower deck space the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the damage control deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

5.5.3 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable, but the diameter is not to exceed 300 mm.

5.5.4 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted up to a diameter of 750 mm within the forward $0,25L_R$.

5.5.5 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

5.5.6 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

Section 6
Air pipes

6.1 General

6.1.1 Air and sounding pipes are to comply with the requirements of Vol 2, Pt 7, Ch 2,10.

6.1.2 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

6.1.3 Air pipes are to be situated clear of areas where damage may occur, such as RAS landing areas and store routes or helicopter decks.

6.2 Height of air pipes

6.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 760 mm on exposed decks immediately above the design draught, e.g. quarter decks and well decks.
- 450 mm measured above deck sheathing, where fitted elsewhere.

6.2.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances as required by 6.3.1 are to be of an approved automatic type.

6.2.3 The height of air pipes may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by Pt 1, Ch 1,1.1. An increase in height may also by required or recommended by Naval Authorities when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings, *see also* Pt 6, Ch 3.

6.2.4 Air pipes are generally to be led to an exposed deck. *See also* Vol 2, Pt 7, Ch 2,10.4.4.

6.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the design waterline.

6.2.6 The minimum wall thickness of air pipes in positions indicated in 6.2.1 is to be:

- 6,0 mm for pipes of 80 mm external diameter or smaller.
- 8,5 mm for pipes of 165 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

6.2.7 Air pipe coaming heights may be reduced on ships assigned a service area notation **SA4**. Coaming heights are to be as high as practicable, with a minimum height of 300 mm.

6.3 Closing appliances

6.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water (*see also* 6.2.2 and Vol 2, Pt 7, Ch 2,10.6.2).

6.3.2 Closing appliances are to be of an approved automatic type when, with the ship at its design draught, the openings are immersed at an angle of heel of θ_{df} or, the angle of down flooding if this is less than θ_{df}. *See also* Ch 2,1.3. The Naval Authority may prohibit openings which are immersed below the θ_{df} angle.

6.3.3 Where the closing appliances are not of an automatic type, provision is to be made for relieving vacuum when the tanks are being pumped out.

Section 7
Scuppers and sanitary discharges

7.1 General

7.1.1 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

7.1.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

7.1.3 Scuppers and discharges which drain spaces below the weather deck, or spaces within intact superstructures or deckhouses on the weather deck, fitted with efficient weathertight doors, are to be led overboard in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) When at the design draught, the deck edge is not immersed when the ship heels to 5°; and
(b) the scuppers are fitted with means of preventing water from passing inboard in accordance with 7.2.

7.1.4 In ships where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle, magazines or hangar spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. Where the design capacity of the drencher system exceeds an application of water at a rate 5 litres per square metre of deck area per by 10 per cent or more, the scupper area will require to be increased accordingly. After installation the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build-up of water on the deck. The mouth of the scupper is to be protected by bars.

7.1.5 Where a sewage system is fitted, the shipside valves on the discharge pipe from the effluent tank(s) and the by-pass system are to comply with 7.2.

7.1.6 The minimum wall thickness of pipes not indicated in 7.2.6 is to be:

4,5 mm for pipes of 155 mm external diameter or smaller.

6,0 mm for pipes of 230 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

7.1.7 For the use of non-metallic pipe, *see* Vol 2, Pt 7, Ch 1,11.

7.1.8 Scuppers and discharge pipes should not normally pass through oil fuel tanks. Where scuppers and discharge pipes pass, unavoidably, through oil fuel tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way, derived from the appropriate Chapters, but need not exceed 19 mm.

7.1.9 Piping within tanks is to be tested in accordance with the Naval Ship Survey Procedures Manual.

7.1.10 All piping is to be adequately supported.

7.2 Closing appliances

7.2.1 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the damage control deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. A machinery space, whether manned or unattended (i.e. with **UMS** notation), is considered accessible. Spaces with access only by bolted manholes are not considered accessible.

7.2.2 Where an approved fire pressure waterspray fire-extinguishing system is provided in an enclosed vehicle space, magazines or hangar spaces, the scupper controls are to be operated from a position above the damage control deck, and outside the space protected by the fire-extinguishing system, and are to be protected from mechanical damage.

7.2.3 Where the vertical distance from the design draught to the inboard end of the discharge pipe exceeds $0{,}01L_R$ the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions.

7.2.4 Where the vertical distance from the design waterline to the inboard end of the discharge pipe exceeds $0{,}02L_R$, a single automatic non-return valve without positive means of closing may be fitted, *see* Fig. 4.7.1.

7.2.5 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship. For discharges which are closed at sea, a single screw down valve operated from the weather deck is considered to provide sufficient protection.

7.2.6 Scuppers and discharge pipes originating at any level which penetrate the shell either more than 450 mm below the weather deck or less than 600 mm above the design draught, are to be fitted with an automatic non-return valve at the shell. This valve, unless required by 7.1.3, may be omitted provided the piping has a minimum wall thickness of:

- 7,0 mm for pipes of 80 mm external diameter or smaller.
- 10,0 mm for pipes of 180 mm external diameter.
- 12,5 mm for pipes of 220 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation. Unless required by 7.1.8, the maximum thickness need not exceed 12,5 mm.

7.2.7 The outboard valve is to be mounted directly on the shell and secured in accordance with Vol 2, Pt 7, Ch 1. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

7.2.8 If a valve is required by 7.1.3, this valve should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the weather deck, the valve is to be capable of being controlled from an easily accessible position above the weather deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

7.2.9 Valves for maintaining watertight integrity such as ship side valves and their fittings (other than those on scuppers and sanitary discharges), are to comply with the requirements of Vol 2, Pt 7, Ch 1 and Ch 2.

7.3 Rubbish chutes and similar discharges

7.3.1 Rubbish chutes and similar discharges should be constructed of mild steel piping or plating of shell thickness. Other materials will be specially considered. Openings are to be kept clear of the sheerstrake and areas of high stress concentration.

7.3.2 Rubbish chute hoppers are to be provided with a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time. The hopper cover is to be secured closed when not in use, and a suitable notice displayed at the control position.

7.3.3 Where the inboard end of the hopper is less than $0{,}01L_R$ above the design draught, a suitable valve with positive means for closing is to be provided in addition to the cover and flap in an easily accessible position above the design draught. The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a suitable notice displayed at the valve operating position.

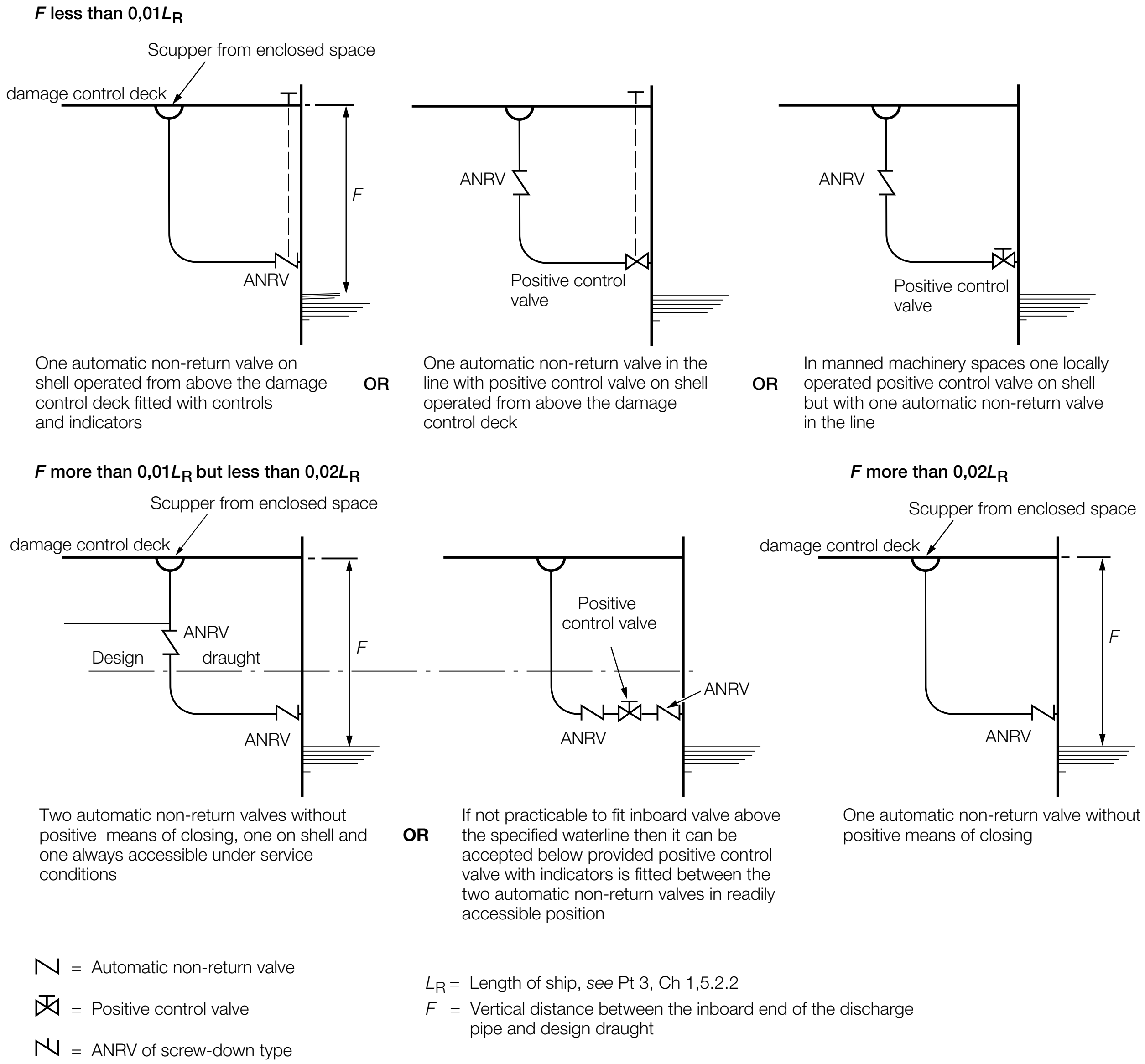


Fig. 4.7.1 Diagrammatic arrangement of discharge valves

7.4 Materials for valves, fittings and pipes

7.4.1 All shell fittings and valves required by 7.2 are to be of steel, bronze or other approved ductile material; ordinary cast iron or similar material is not acceptable. Materials are to satisfy the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (Vol 1, Part 2).

7.4.2 All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

7.4.3 The lengths of pipe attached to the shell fittings, elbow pieces or valves are to be of galvanised steel or other equivalent approved material.

Section 8
Bulwarks and other means for the protection of crew and embarked personnel

8.1 General requirements

8.1.1 Bulwarks or guard-rails are to be provided at the boundaries of exposed decks. Bulwarks or guard-rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 8.2. Consideration will be given to cases where this height would interfere with the normal operation of the ship. Guard-rails provided around aircraft operating areas may be of the type which drop outwards with nets to the satisfaction of the Naval Authority, provided access is restricted to essential personnel. Where bulwarks or rails are undesirable e.g. for radar signature purposes, alternative equivalent arrangements will require to be provided.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with 8.3.

8.1.3 The opening below the lowest course of guard-rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of ships with rounded gunwales, the guard-rail supports are to be placed on the flat of the deck.

8.1.4 Satisfactory means, in the form of guard-rails, lifelines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew and embarked personnel in getting to and from their quarters, the machinery space and all other parts used in the necessary operation of the ship. Where a well-lighted and ventilated underdeck passage (clear opening 0,8 m wide, 2 m high) is provided it is to be as close as practicable to the weather deck, connecting and providing access to the following locations:

- between superstructures
- from forward and aft superstructures to the fore end and aft end respectively.

8.1.5 Chains are only permitted in short lengths in way of access openings.

8.1.6 Gangways or walkways may be omitted on ships assigned a service area notation **SA4**.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of $0{,}93L_R$ is to be not more than 1,2 m. Elsewhere, bulwark stays are to be not more then 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for RAS points, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2 s \quad \text{cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, in accordance with 9.2.1

L_R = length of ship, in metres (as defined in Ch 1,5.1), but to be not greater than 100 m.

8.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the ship, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

8.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.3 Freeing arrangements

8.3.1 The following requirements are applicable to all ship types.

8.3.2 Where bulwarks on the weather decks or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

8.3.3 The minimum freeing area on each side of the ship, for each well on the weather deck is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less: area required = $0{,}7 + 0{,}035l$ m^2

(b) where the length, l, exceeds 20 m area required = $0{,}07l$ m^2

l need not be taken greater than $0{,}7L_R$, where L_R is the length of the ship as defined in Ch 1,5.2.

8.3.4 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

8.3.5 The minimum freeing area for each well on a superstructure is to be half the area calculated from 8.3.3.

8.3.6 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

8.3.7 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

8.3.8 In ships with no sheer the freeing area as calculated from 8.3.3 is to be increased by 50 per cent. Where the sheer is less than the standard, as given in Table 4.8.1, the percentage is to be obtained by linear interpolation.

Table 4.8.1 Standard sheer profile

Position from A.P.	Ordinate (in mm)
A.P.	$25\left(\frac{L_R}{3} + 10\right)$
$0,16L_R$	$11,1\left(\frac{L_R}{3} + 10\right)$
$0,33L_R$	$2,8\left(\frac{L_R}{3} + 10\right)$
$0,5L_R$	0
$0,67L_R$	$5,6\left(\frac{L_R}{3} + 10\right)$
$0,83L_R$	$22,2\left(\frac{L_R}{3} + 10\right)$
F.P.	$50\left(\frac{L_R}{3} + 10\right)$

NOTES
1. Sheer is measured from the deck at side to a line drawn parallel to the keel through the sheer line amidships.
2. In ships with a rake of keel, the sheer is measured in relation to a reference line drawn parallel to the design waterline.

8.3.9 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed 10 per cent of the bulwark area.

8.3.10 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small ships, credit can be given for bollard and fairlead openings where these extend to the deck.

8.3.11 Where a deckhouse has a breadth less than 80 per cent of the beam of the ship, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam, *B*, of the ship, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the ship, this arrangement is considered as two wells, before and abaft the deckhouse.

8.3.12 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

8.3.13 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures and deckhouses, etc., in which water may be shipped and trapped. Deck gear is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

8.3.14 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

8.3.15 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

8.3.16 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port.

8.3.17 All ships are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

8.3.18 Where a ship operates for extended periods in a cold weather environment, *see* Pt 5, Ch 2,4.2.3, closing devices fitted to freeing port arrangements are to remain effective. The arrangement will be specially considered.

8.4 Free flow area

8.4.1 The effectiveness of the freeing port area in bulwarks of vessels not fitted with a continuous deck obstruction, depends on the free flow across the deck.

8.4.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

■ *Section 9* Lagging and lining of structure

9.1 General

9.1.1 Suspended floors are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

9.2 Removal for access

9.2.1 It is recommended that the cabin fittings and linings against the side of the ship be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

9.2.2 Removable linings are to be fitted in areas prone to high structural degradation and areas that are critical to the structural integrity of the hull, to permit examination of these areas.

9.2.3 Decorative linings are to be manufactured of materials resistant to secondary fragmentation and combustion.

Anchoring, Mooring, Towing, Berthing, Launching, Recovery and Docking

Section

■ *Section 1* General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable for ships designed for unrestricted service.

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Character of classification

1.3.1 For classification purposes the character figure **1**, or the character letter **E**, is to be assigned.

1.3.2 To entitle a ship to the character **1** in its classification symbol, equipment in accordance with the requirements of Sections 5, 6, 7, 9 and 10 are to be provided. The regulations governing the assignment of the character figure **1** for equipment are given in Pt 1, Ch 2.

1.3.3 Where Lloyd's Register (hereinafter referred to as 'LR') has agreed that anchoring and mooring equipment, as defined in 1.3.2, need not be fitted in view of the particular service of the ship, the character letter **E** will be assigned. *See also* Pt 1, Ch 2.

1.3.4 For ships intended to be operated only in suitable areas or conditions, other than those included in this Section, which have been agreed by LR, (as defined in Pt 1, Ch 2,3.5) equipment differing from these requirements may be approved if considered suitable for the particular service on which the ship is to be engaged.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment specified in this Section is based on an 'Equipment Number' which is to be calculated as follows:

Equipment Number = $\Delta^{2/3} + 2{,}5A_t + A/10$

where

A = area, in m^2, in profile view, of the hull, superstructures, houses, masts, etc. above the design draught which are within the Rule length of the vessel and also have a breadth greater than $B/4$. *See also* 2.1.2 and 2.1.3

A_t = transverse projected area, in m^2, of the hull and of all superstructures, houses, masts, etc., above the design draught

Δ = displacement, in tonnes, of the ship at its deep draft waterline.

2.1.2 In the calculation of A_t, if a house having a breadth greater than $B/4$ is above a house with a breadth of $B/4$ or less, then the wide house is to be included, but the narrow house ignored.

2.1.3 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining A and A_t. Where a screen or bulwark is of varying height, the portion to be included is to be that length the height of which exceeds 1,5 m.

2.1.4 For ships which have a complex above water transverse profile due to the presence of large plated masts, mast trees, large radar equipment, etc., the equipment number may need to be specially considered.

2.2 Novel ship design

2.2.1 Where a ship is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

■ *Section 3* Service area factors

3.1 General

3.1.1 For details of the service areas referred to in this Section, *see* Pt 5, Ch 2,2.2.

3.2 Service Areas SA1, SA2, SA3, SA4, SAR

3.2.1 For ships designed to operate in any service area, the equipment is to be in accordance with the requirements of Tables 5.5.1 and 5.7.1.

■ *Section 4* Ship type factors

4.1 General

4.1.1 The Equipment Numbers derived from 2.1 are to be corrected by the ship type factors indicated in this Section.

4.2 Ship type factors

4.2.1 NS1 and NS2. Ship type factor k_p = 1,15.

4.2.2 NS3. Ship type factor k_p = 1,0.

■ *Section 5* Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.5.1 is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Ships are to be provided with the number of anchors as specified in Table 5.5.1 on board which must be ready for immediate use.

5.1.5 Where a high degree of redundancy in propulsion and steering and the engine can be brought to readiness quickly, consideration may be given to the fitting of a single anchor where Table 5.5.1 requires the fitting of two anchors, where acceptable to the Naval Authority.

5.1.6 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.1.7 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal ship use, but may be accepted for offshore units, floating cranes, etc. In such cases suitable tests may be required.

5.1.8 Where ships are required to be fitted with kedge anchors they are to be in accordance with Table 5.7.1.

5.2 Materials

5.2.1 The requirements for the manufacture, testing and certification of anchors are contained in Pt 2, Ch 10.

5.3 Anchor stowage

5.3.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.3.2 Hawse pipes and anchor pockets are to be in accordance with 9.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.4 High Holding Power (HHP) type anchors

5.4.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested at sea to show that they have holding powers of at least twice those approved of standard stockless anchors of the same mass.

5.4.2 If approval is sought for a range of sizes, then at least three sizes are to be tested, representative of the bottom, middle and top of the range. The smallest anchor in the range is to be tested. The largest anchor to be tested is to have a mass not less than half that of the largest anchor in the range. If the range is large such that the middle anchor to be tested is greater than twice the mass of the smallest anchor or less than half the mass of the largest anchor to be tested, then additional anchors may require to be tested.

5.4.3 The tests are to be conducted on not less than three different types of bottom, which are normally to be soft mud or silt, sand or gravel, and hard clay or similarly compacted material.

Table 5.5.1 Equipment – HHP Bower anchors and chain cables

Equipment number			Stockless bower anchors		Stud link chain cables for bower anchors			
Exceeding	Not exceeding	Equipment Letter	Number	Mass of anchor, in kg	Total length, in metres		Diameter, in mm	
						Grade U1	Grade U2	Grade U3
50	70	A	2	135	220	14	12,5	–
70	90	B	2	180	220	16	14	–
90	110	C	2	225	247,5	17,5	16	–
110	130	D	2	270	247,5	19	17,5	–
130	150	E	2	315	275	20,5	17,5	–
150	175	F	2	360	275	22	19	–
175	205	G	2	428	302,5	24	20,5	–
205	240	H	2	495	302,5	26	22	20,5
240	280	I	2	585	330	28	24	22
280	320	J	2	675	357,5	30	26	24
320	360	K	2	765	357,5	32	28	24
360	400	L	2	855	385	34	30	26
400	450	M	2	968	385	36	32	28
450	500	N	2	1080	412,5	38	34	30
500	550	O	2	1193	412,5	40	34	30
550	600	P	2	1305	440	42	36	32
600	660	Q	2	1440	440	44	38	34
660	720	R	2	1575	440	46	40	36
720	780	S	2	1710	467,5	48	42	36
780	840	T	2	1845	467,5	50	44	38
840	910	U	2	1980	467,5	52	46	40
910	980	V	2	2138	495	54	48	42
980	1060	W	2	2295	495	56	50	44
1060	1140	X	2	2475	495	58	50	46
1140	1220	Y	2	2655	522,5	60	52	46
1220	1300	Z	2	2835	522,5	62	54	48
1300	1390	A †	2	3038	522,5	64	56	50
1390	1480	B †	2	3240	550	66	58	50
1480	1570	C †	2	3443	550	68	60	52
1570	1670	D †	2	3668	550	70	62	54
1670	1790	E †	2	3938	577,5	73	64	56
1790	1930	F †	2	4208	577,5	76	66	58
1930	2080	G †	2	4500	577,5	78	68	60
2080	2230	H †	2	4838	605	81	70	62
2230	2380	I †	2	5175	605	84	73	64
2380	2530	J †	2	5518	605	87	76	66
2530	2700	K †	2	5850	632,5	90	78	68
2700	2870	L †	2	6225	632,5	92	81	70
2870	3040	M †	2	6525	632,5	95	84	73
3040	3210	N †	2	6975	660	97	84	76
3210	3400	O †	2	7425	660	100	87	78
3400	3600	P †	2	7875	660	102	90	78
3600	3800	Q †	2	8325	687,5	105	92	81
3800	4000	R †	2	8775	687,5	107	95	84
4000	4200	S †	2	9225	687,5	111	97	87
4200	4400	T †	2	9675	715	114	100	87
4400	4600	U †	2	10125	715	117	102	90
4600	4800	V†	2	10575	715	120	105	92
4800	5000	W†	2	11025	742,5	122	107	95
5000	5200	X†	2	11550	742,5	124	111	97
5200	5500	Y†	2	12075	742,5	127	111	97
5500	5800	Z†	2	12675	742,5	130	114	100
5800	6100	A*	2	13350	742,5	132	117	102
6100	6500	B*	2	14100	742,5	–	120	107
6500	6900	C*	2	15000	770	–	124	111
6900	7400	D*	2	16125	770	–	127	114
7400	7900	E*	2	17250	770	–	132	117
7900	8400	F*	2	18375	770	–	137	122
8400	8900	G*	2	19500	770	–	142	127
8900	9400	H*	2	20625	770	–	147	132
9400	10000	I*	2	21750	770	–	152	132
10000	10700	J*	2	23250	770	–	157	137
10700	11500	K*	2	24750	770	–	157	142
11500	12400	L*	2	26625	770	–	162	147
12400	13400	M*	2	28875	770	–	–	152
13400	14600	N*	2	31500	770	–	–	157
14600	16000	O*	2	34500	770	–	–	162

5.4.4 The tests are to be at full scale using a tug or other suitable vessel and the holding force measured by dynamometer incorporated within the anchor rode system. The dynamometer used is to produce a continuous readout in numerical and graphical form. A scope of 10 is recommended for the anchor cable, but in no case is a scope of less than six to be used. The same scope is to be used for the anchor for which approval is sought and the anchor that is being used for comparison purposes.

5.4.5 High holding power anchors are to be of a design that will ensure that the anchors will take effective hold of the sea bed without undue delay and will remain stable, for holding forces up to those required by 5.6.1, irrespective of the angle or position at which they first settle on the sea bed when dropped from a normal type of hawse pipe. In case of doubt, a demonstration of these abilities may be required.

5.5 Super High Holding Power (SHHP) type anchors

5.5.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

5.5.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.5.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

5.6 Tolerances

5.6.1 The mass of each bower anchor given in Table 5.5.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.6.2 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

5.6.3 When stocked bower or kedge anchors are to be used, the mass 'ex stock' is to be not less than 80 per cent of the mass given in Table 5.5.1 for ordinary stockless bower anchors and Table 5.7.1 for kedge anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc., but excluding the stock.

5.7 Identification

5.7.1 Identification of anchors which have been tested is to be in accordance with Pt 2, Ch 10.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.2 Chain cable

6.2.1 The length and diameter of chain cable is to be as indicated in Table 5.5.1.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by Table 5.5.1.

6.2.3 Chain cables are to be steel in accordance with the requirements of Pt 2, Ch 10.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to 6.2.3 special consideration will be given to the use of chain cable of alloy steel. Alloy steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with Pt 2, Ch 10.

6.2.7 Where kedge anchors are used in association with chain cable, this cable may be either stud link or short link.

6.2.8 Test certificates issued in accordance with Pt 2, Ch 10 are to be signed by the Surveyors when the cables are placed on board the ship.

6.2.9 Arrangements are to be provided for the safe use of cable when mooring to a buoy, securing alongside hazardous or exposed jetties or preparing to be towed. Alternative arrangements to meet these requirements without the use of cable are to be submitted for consideration.

6.3 Wire rope

6.3.1 Steel wire ropes are to be manufactured, tested and certified as required by Pt 2, Ch 10.

6.4 Cable clench

6.4.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

6.5 Cable stopping and release arrangements

6.5.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outside the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

6.6 Cable locker

6.6.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.6.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.6.3 Chain lockers fitted abaft the collision bulkhead are to be weathertight and the space to be efficiently drained.

■ *Section 7* Mooring ropes

7.1 Mooring ropes

7.1.1 Ships under 90 m require mooring lines as specified in Table 5.7.1. Mooring lines may be of wire, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Pt 2, Ch 10. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.1.2 The lengths of individual mooring lines in Table 5.7.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.1.3 Ships 90 m and over in length do not require mooring lines as a classification item. It is recommended, however, that the sum of the strengths of all the mooring lines supplied to such ships should be not less than the Rule breaking load of one anchor cable as required by Table 5.5.1, based on Grade U2 chain. On ships regularly using exposed berths, twice the above total strength of mooring ropes is desirable.

7.1.4 It is recommended that not less than four mooring lines be carried on ships exceeding 90 m in length, and not less than six mooring lines on ships exceeding 180 m in length. The length of mooring lines should be not less than 200 m, or the length of the ship, whichever is the lesser.

7.1.5 For ease of handling, fibre ropes should be not less than 20 mm diameter. All ropes having breaking strengths in excess of 736,0 kN and used in normal mooring operations are to be handled by, and stored on, suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490,0 kN

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Pt 2, Ch 10. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with Pt 2, Ch 10.

7.4 Bollards, fairleads and bull rings

7.4.1 Means are to be provided to enable mooring lines to be adequately secured on board ship.

7.4.2 Details showing the proposed scantlings of support arrangements for the bollards, fairleads and bull rings are to be submitted.

7.4.3 It is recommended that the total number of suitably placed bollards on either side of the ship and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended.

7.4.4 Bollards, fairleads and bull rings are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other equivalent arrangements will be specially considered.

Table 5.7.1 Equipment – Kedge anchors, wires and mooring lines

Equipment Number		Equipment Letter	Mass of stockless kedge anchor in kg	Kedge anchor wire or chain (1) & (2)		Mooring lines (2)		
Exceeding	Not Exceeding			Minimum length in metres	Minimum breaking strength, in kN	Number	Minimum length of each line in metres	Minimum breaking strength, in kN
50	70	A	68	110	46	2	100	34,3
70	90	B	90	110	58	2	100	36,8
90	110	C	113	124	75	2	110	39,2
110	130	D	135	124	90	2	110	44,1
130	150	E	158	138	90	2	120	49,0
150	175	F	180	138	122	2	120	54,4
175	205	G	214	151	106	2	120	58,0
205	240	H	248	151	140	2	120	64,2
240	280	I	292	165	166	3	120	71,1
280	320	J	338	179	195	3	140	78,5
320	360	K	383	179	225	3	140	85,8
360	400	L	428	193	257	3	140	93,2
400	450	M	484	193	292	3	140	100,5
450	500	N	540	206	328	3	140	107,9
500	550	O	597	206	328	4	160	112,8
550	600	P	653	220	366	4	160	117,7
600	660	Q	720	220	406	4	160	122,6
660	720	R	788	220	448	4	160	127,5
720	780	S	855	233	491	4	170	132,4
780	840	T	923	233	540	4	170	137,3
840	910	U	990	233	585	4	170	142,2
910	980	V	1069	248	635	4	170	147,1
980	1060	W	1148	248	685	4	180	156,9
1060	1140	X	1238	248	685	4	180	166,7
1140	1220	Y	1328	261	740	4	180	176,5
1220	1300	Z	1418	261	795	4	180	186,3
1300	1390	A †	1519	261	855	4	180	196,1
1390	1480	B †	1620	275	905	4	180	205,9
1480	1570	C †	1721	275	970	5	190	215,7
1570	1670	D †	1834	275	1030	5	190	225,6
1670	1790	E†	1969	289	1095	for ships over 90 m in length, *see* 7.1.3		
1790	1930	F†	2104	289	1155	"		
1930	2080	G†	2250	289	1225	"		
2080	2230	H†	2419	302	1290	"		
2230	2380	I†	2588	302	1395	"		
2380	2530	J†	2759	302	1505	"		
2530	2700	K†	2925	316	1580	"		
2700	2870	L†	3113	316	1690	"		
2870	3040	M†	3263	316	1805	"		
3040	3210	N†	3488	330	1805	"		
3210	3400	O†	3713	330	1925	"		
3400	3600	P†	3938	330	2045	"		
3600	3800	Q†	4163	344	2130	"		
3800	4000	R†	4388	344	2255	"		
4000	4200	S†	4613	344	2340	"		

NOTES

1. The rope used for kedge anchor wire is to be constructed of not less than 72 wires, made up into six strands.
2. Steel wire and fibre ropes used for mooring lines and kedge anchors are to meet the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, Vol 1, Pt 2, Ch 10,6 and 7* respectively.
3. Wire ropes for mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.

7.4.5 The design load to be applied is to be the greater of:

- Twice the maximum breaking strength of the mooring line anticipated to be used throughout the service life of the ship
- Twice the breaking strength of the mooring line according to Table 5.7.1.

7.4.6 The selection of shipboard fittings is to be made by the shipyard in accordance with an Industry standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards) accepted by the Society. When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with 7.4.5.

7.4.7 Arrangement of the reinforced members (carling) beneath shipboard fittings is to consider any variation of direction (laterally and vertically) of the mooring forces (which is to be not less than the design load as per 7.4.5) acting through the arrangement of connection to the shipboard fittings.

7.4.8 The acting point of the mooring force on shipboard fittings is to be taken at the attachment point of a mooring line or equivalent.

7.4.9 The stresses in shipboard fittings associated with mooring are not to exceed those given in Table 5.8.2 considering the design load defined in 7.4.5.

7.4.10 The SWL of each shipboard fitting is not to exceed one half of the design load as per 7.4.5. It is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. The SWL with its intended use is to be note in the towing and mooring arrangement plan or other information available on board for the guidance of the Master. These requirements for SWL apply for a single post basis (no more than one turn of one cable). The arrangement plan is to explicitly prohibit the use of mooring lines outside of their intended function.

7.5 Mooring winches

7.5.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor's satisfaction.

7.5.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also* 7.4.1.

■ *Section 8* Towing arrangements

8.1 Definition

8.1.1 Towing can be defined as either receiving motive assistance from, or rendering it to, another vessel.

8.2 Application

8.2.1 The towing arrangements specified in this section are applicable to NS1, NS2 and NS3 category ships carrying the corresponding optional towing arrangement notation.

8.2.2 The strength of strong points, fittings and machinery are to be proof tested unless type approved.

8.2.3 In general, ships complying with the requirements of this section will be eligible to be classed with the notation **TA1**, TA2 or **TA3**.

8.3 Materials

8.3.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (Vol 1, Part 2).

8.3.2 Towing hawsers and towing pennants can be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of steel wire or fibre towlines are to comply with Pt 2, Ch 10,6 and 7 respectively.

8.3.3 Where a length of chafing chain is included in the arrangement it is to comply with Pt 2, Ch 10.

8.4 Information required

8.4.1 Plans are to be of sufficient detail for plan approval purposes. Plans covering the following items are to be submitted for approval:

- Strong points, bollards and fairleads.
- Support structure and foundations of towing equipment.

8.4.2 The following supporting documents are to be submitted for information:

- Towing arrangements, including lines of action, magnitudes and corresponding points of application of towline pulls on towing equipment.
- Details of the breaking strength of the components of the towline system, together with maximum pull and brake holding power, or equivalent, of mooring winches or anchor windlasses included in the towing arrangement.
- Manufacturer's certificates for all steel or fibre rope used in the arrangement.
- Proof that bollards or fairleads used in the arrangement comply with 8.6.5.

8.4.3 The Safe Working Load (SWL) of all towing arrangement components is to be noted in the towing and mooring arrangement plan or equivalent information on board the vessel, *see* 8.6.11.

8.5 Towing arrangements

8.5.1 A towing arrangement is to be provided at both the fore and aft end of the ship.

8.5.2 The fixed towing equipment is to comprise a securing arrangement which is a strong point and may be in the form of a stopper, bracket, deck clench, windlass or towing slip. A fairlead, rollers or other appropriate towline guides as necessary are to be included in the arrangement.

8.5.3 Loose towing equipment is to comprise a towing hawser and a towing pennant. The towing pennant may comprise a length of chafing chain. In the absence of a length of chafing chain suitable arrangements e.g. a low friction sheath are to be provided.

8.5.4 Fairleads and guides are to be designed so as to prevent excessive bending stress in the towing hawser, towing pennant or chafing chain, whichever is applicable. The bending ratio of the guides bearing surface to the diameter of the applicable towline element is not to be less than 7 to 1. For fibre rope towing hawsers and towing pennants the bending ratio is to comply with the rope manufacturer's specification.

8.5.5 The fairlead or guide is to have an opening large enough to allow the passage of the largest element of the loose towing equipment.

8.5.6 The fairlead or guide is to be fitted as close to the deck as practicable and in a position so that the tow will be approximately parallel to the deck when under tension between the strong point and the guide.

8.5.7 To avoid chafing, the arrangement is to be designed so that no element of the loose towing equipment, when under tension is to contact with the ships hull at any point other than those specified as a securing arrangement, fairlead or guide. The final point of contact of the towline with the ship is to be positioned as close as practicable to the centre line so as to lower the affect on manoeuvrability.

8.5.8 The chafing arrangement is to extend a minimum of 3 m outboard of the fairlead or guide when in the deployed position and 2 m inboard.

8.5.9 The loose towing equipment is to be located as near as practicable to the strong point and is to be designed to be capable of being rigged and deployed in the absence of power. It is recommended that extra loose gear meeting the requirements of this Section be carried on board to provide for redundancy.

8.5.10 The minimum length of the towing hawser is to be the length of the summer load waterline plus 50 m with a minimum length of 180 m.

8.5.11 Irrespective of strength requirements, no fibre rope is to be less than 20 mm in diameter.

8.5.12 The SWL of each shipboard fitting is to be clearly marked, by weld bead or equivalent, on each of the fittings used for towing, *see* 8.6.11.

8.6 Strength requirements for towing arrangements

8.6.1 The Maximum Breaking Load (hereinafter referred to as *MBL*), in tonnes, of the towing hawser required to be carried on board the ship can be calculated as follows:

$$MBL = (0{,}03\Delta^{2/3} + (C_{mw} A_t))\,K$$

where

Δ = displacement, in tonnes, to the deep draft waterline

C_{mw} = wind speed coefficient, which is to be taken from Table 5.8.1 for the relevant notation

K = weather factor, which is to be taken from Table 5.8.1 for the relevant notation

A_t = transverse projected area, in m^2, of the hull and of all superstructures, houses, masts, etc. above the design draught

Table 5.8.1 Design weather factors

Applicable notation	Wind speed coefficient, C_{mw}	Weather factor, K
TA1	0,0150	8
TA2	0,0129	7,2
TA3	0,0108	6,3

8.6.2 The strength of other loose towing equipment e.g. links, shackles rings and chafing chain is to be determined on the basis of an applied load equal to 1,3 times the MBL of the towing hawser.

8.6.3 The strength of strong points, bollards, fair leads and supporting structure is to be determined on the basis of an applied load equal to twice the MBL of the towing hawser.

8.6.4 The stress in all loose and fixed towing equipment constructed of steel is not to exceed that given in Table 5.8.2 considering the applied loads in 8.6.2 and 8.6.3. Special consideration will be given if the vessel and/or towing equipment is not constructed of steel.

Table 5.8.2 Allowable stress

	Bending stress, in N/mm^2	Shear stress, in N/mm^2	Combined stress, in N/mm^2
Allowable stress	$\dfrac{235}{k}$	$\dfrac{135}{k}$	$\dfrac{235}{k}$

where

$k = \dfrac{235}{\sigma_0}$

σ_0 = specified minimum yield strength of the material, in N/mm^2

8.6.5 Arrangement of the reinforced members (carling) beneath shipboard fittings is to consider any variation of direction (laterally and vertically) of the mooring forces (which is to be not less than the design load as per 8.6.3) acting through the arrangement of connection to the shipboard fittings.

8.6.6 For the assessment of fairleads and their supporting structure, due consideration must be given to lateral loads. The strength of the fairlead must be sufficient for all angles of towing load up to 90° horizontally from the ship's centreline and 30° vertically from the horizontal plane.

8.6.7 For the assessment of a strong point and its supporting structure, the applied load is to be in the direction that the towing pennant or towing hawser will take up during normal deployment. It is also to be applied at the maximum height possible above the deck for that specific type of strong point.

8.6.8 The structural arrangements of strong points, bollards and fairleads are to be such that continuity will be ensured. Abrupt changes in section; sharp corners and other points of stress concentration are to be avoided.

8.6.9 Strong points and fairleads are to be fitted in way of a transverse or longitudinal deck girder or beam to facilitate efficient distribution of the towing load.

8.6.10 Mooring winches included in the towing arrangement are to have an appropriate brake holding power to that of the *MBL* of the towing hawser. The holding capability should be calculated for the outermost towline layer on the winch drum at which towing will be performed.

8.6.11 The SWL of each towing arrangement component is to be no greater than one half of the design load applied.

■ *Section 9*
Windlass and capstan design and testing

9.1 General

9.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the ship. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

9.1.2 The windlass seating to be designed to loads no less than the maximum pull developed by the windlass.

9.1.3 Windlasses may be hand or power operated, subject to the requirements of 9.2.3.

9.1.4 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

9.1.5 The windlass, anchoring capstans and winches are to be of types approved by LR.

9.1.6 On ships equipped with anchors having a mass of over 50 kg, windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

9.1.7 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and

(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

9.2 Performance

9.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:

  (i) For specified design anchorage depths up to 82,5 m:

Cable grade	Duty pull, *P*, in N
U1	$36{,}79 d_c^2$
U2	$41{,}68 d_c^2$
U3	$46{,}60 d_c^2$

  (ii) For specified design anchorage depths greater than 82,5m:

$$P_1 = P + (D_a - 82{,}5)\ 0{,}214 d_c^2 \text{ N}$$

where d_c is the chain diameter, in mm, D_a is the design anchorage depth, in m, P is the duty pull for anchorage depth up to 82,5 m and P_1 is the duty pull for the anchorage depths greater than 82,5 m.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:

  (i) short term pull:
  1,5 times the continuous duty pull as defined in 9.2.1(a).

  (ii) anchor breakout pull:

$$12{,}18 W_a + \frac{7{,}0 L_c\, d_c^2}{100} \quad \text{N}$$

where

L_c is the total length of chain cable on board, in metres, as given by Table 5.5.1

W_a is the mass of bower anchor (kg) as given in Table 5.5.1.

(c) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

$$K_b\, d_c^2\, (44 - 0{,}08 d_c) \quad \text{N}$$

where

K_b is given in Table 5.9.1

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

(d) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position the following notice is to be displayed:

'The brake is rated to permit controlled descent of the anchor and chain only.
The chain stopper is to be used at all times whilst riding at anchor.'

Table 5.9.1 Values of K_b

Cable grade	K_b	
	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41	7,85
U2	6,18	11,00
U3	8,83	15,7

9.2.2 Windlass performance characteristics specified in 9.2.1 and 9.3.2 are based on the following assumptions:

(a) One cable lifter only is connected to the drive shaft.
(b) Continuous duty and short term pulls are measured at the cable lifter.
(c) Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
(d) The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
(e) Hawse pipe efficiency assumed to be 70 per cent.

9.2.3 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 150 N for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

9.2.4 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

9.3 Tests and trials

9.3.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 9.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

9.3.2 During trials on board the ship the windlass is to be shown to be capable of:

(a) for all specified design anchorage depths: raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min.
(b) for specified design anchorage depths greater than 82,5 m, in addition to (a): raising the anchor from the specified design anchorage depth to a depth of 82,5 m at a mean speed of 3 m/min.

Following trials, the ship will be eligible to be assigned a descriptive note 'Specified design anchorage depth. . . metres' which will be entered in column 6 of the *Register Book*.

9.4 Seatings

9.4.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 10* Structural details

10.1 General

10.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

10.2 Bulbous bow and wave piercing bow arrangements

10.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Part 6.

10.3 Hawse pipes and anchor recesses

10.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

10.3.2 The hawse pipes are to be of sufficient size and thickness with a minimum diameter not less than 12 times the diameter of the chain cable. The arrangement is to give an easy lead for the cable to the windlass.

10.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see* 10.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

10.3.4 The silting of the hawspipe for conventional bower anchors depends upon the shape of the forebody and the bow contour of the vessel and sufficient clearance is to be given between the anchor flukes in the most critical position and other underwater bow contours including sonar domes. Alternatively, where bow sonar domes are fitted the main bower anchor is to be positioned on the centreline with recesses anchor is to be positioned on the centreline with recessed anchor stowage and the sheet/stream anchor, conventionally positioned, is only to be used in an emergency.

10.4 Spurling pipes

10.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers.

10.5 Local reinforcement

10.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

■ *Section 11*
Launch and recovery, berthing and docking arrangements

11.1 Berthing loads

11.1.1 To resist loads imposed by tugs and berthing operations all structure within a 1,0 m strip centred 1,0 m above the deep waterline. It should be able to withstand the following pressure P_b:

$$P_b = \left(\frac{g\Delta}{800}\right) \text{ kN/m}^2$$

where

Δ = deep displacement, in tonnes.

11.1.2 If $L_R > 200$ m, or the ship is able to have significantly different loading conditions, the strip is to be taken from 1,5 m above the light waterline to 2,5 m above the deep waterline.

11.1.3 Ships with markings to indicate location of internal structure designed specifically for berthing purposes will be specially considered.

11.2 Docking loads

11.2.1 Docking a ship on blocks imposes high vertical loads on the keel. The keel and double bottom structure is to be assessed using a simplified method where a line load at the keel equal to the following equation is distributed equally over blocks in that section. For block spacing where a number of blocks are spaced equally between the transverse bulkheads, the load on the keel can be taken as a distributed line load.

$$F_{DL} = \frac{g\,W_c}{L_c} \text{ kN/m}$$

where

W_c = weight of the length between main transverse bulkheads in tonnes

L_c = distance between main transverse bulkheads, in metres.

11.2.2 For ships with an after cut-up or a significant rake of stem where there is a considerable overhang increasing the load at the after or fore end of the keel. It may be assumed that the increase in load due to the overhang will extend forward from the cut up a distance equal to twice the length of the overhang and will be distributed parabolically, *see* Fig. 5.11.1.

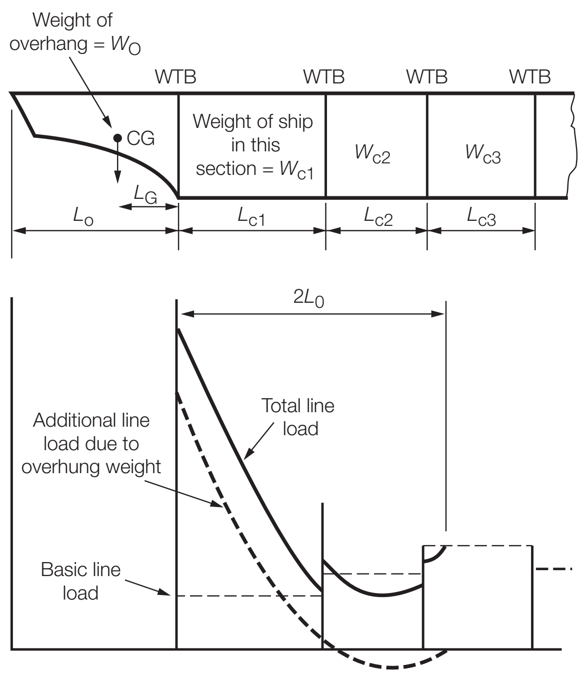


Fig. 5.11.1
Calculation of dock block loads in way of the after cut-up

11.2.3 When an overlap of the forward and aft overhang correction curves occurs both curves are to be included in the total line load over a section.

11.2.4 It may then be shown that the mass per unit length to be added at each dock block at forward of the cut-up is given by the following equation:

$$W_{oh} = \frac{3g\, W_o\, k_{dl}}{4 L_o^2} \text{ kN/m}$$

where

$$k_{dl} = (2L_o + 3L_G)\left(\frac{x}{L_o}\right)^2 - 2\,(3L_o + 4L_G)\left(\frac{x}{L_o}\right) + 4\,(L_o + L_G)$$

x = distance forward of after cut-up, in metres
W_o = weight of overhang, in tonnes
W_c = weight of section between main transverse bulkheads, in tonnes
L_o = length of overhang, in metres
L_c = length between main transverse bulkheads
L_G = position of centre of gravity aft of after cut-up.

11.2.5 Unusual docking procedures or arrangements will be specially considered.

11.3 Launching loads

11.3.1 The launching loads are to be checked by the shipbuilder using conventional analytical methods appropriate to the method of launch. If via a slipway, the structure in way of the fore poppet should be suitable for the high loads that will be transmitted in this area. If adequate structure is not available, temporary stiffening is to be arranged.

11.3.2 The global strength of the hull girder is to be adequate under the loads imposed by launching. In particular for NS1 ships.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components and the requirements are to be applied in conjunction with the relevant Chapters of Part 6.

1.2 Classification notations

1.2.1 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional optional class notations defined in Pt 1, Ch 2.

1.3 Information and plans required to be submitted

1.3.1 The information and plans required to be submitted are as specified in the Pt 6, Ch 1, 2.2, applicable to the particular ship type and in this Chapter where related to particular items and notations.

■ *Section 2* Structural Design Assessment

2.1 Structural Design Assessment notation – SDA

2.1.1 Where scantlings are primarily examined using finite element methods for both the overall and detailed structural capability of the ship using Lloyd's Register (hereinafter referred to as 'LR') approved procedures, the notation **SDA** (Structural Design Assessment) may be assigned and will be entered in the *Register Book*.

■ *Section 3* Fatigue Design Assessment

3.1 Fatigue Design Assessment notation – FDA

3.1.1 Where the fatigue capability of the ship has been assessed using LR approved procedures, the notation **FDA** (Fatigue Design Assessment) may be assigned and will be entered in the *Register Book*.

■ *Section 4* Construction Monitoring

4.1 Construction Monitoring notation – CM

4.1.1 **CM** (Construction Monitoring) notation may be assigned to a ship and will be entered in the *Register Book* if extended controls on structural alignment, fit-up and workmanship standards are applied to critical areas identified by structural design assessment, specified in 2.1.1, and fatigue design assessment specified in 3.1.1, in accordance with LR approved procedures.

■ *Section 5* Ship Event Analysis

5.1 Ship Event Analysis – Class notations SEA(HSS-n), SEA(VDR), SEA(VDR-n)

5.1.1 At the Owner's request, and in order to enhance safety and awareness onboard during ship operation, provisions can be made for the following systems:

(a) A hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship's personnel that these levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable.

(b) A voyage data recorder system that can record the ship's control, navigational, operational and hull response information. This information is recorded and stored in a protective containment unit to enable the analysis of any marine or other incidents.

5.1.2 Where a hull surveillance system is fitted the class notation **SEA(HSS-n)** will be assigned. Where a voyage data recorder system is fitted the class notation **SEA(VDR)** or **SEA(VDR-n)** will be assigned. The extension **-n** signifies the number of fitted strain gauges connected to the system. The appropriate class notation(s) will be entered in column 6 of the *Register Book*, *see also* Pt 1, Ch 2,3.9.6 of the Rules for Ships.

Section 6
Enhanced Scantlings

6.1 Enhanced Scantlings – ES

6.1.1 Where scantlings in excess of the approved Rule requirement are fitted at defined locations as a corrosion margin or for other purposes as specified by the Owner, a notation, **ES**, **'**Enhanced Scantlings', will be assigned. It will be accompanied by a list giving items to which the enhancement has been applied and the increase in scantling. For example, the item 'bottom shell (strakes A, B, C, D) + 2' will indicate that an extra 2 mm has been fitted to the bottom shell of the ship for the particular strakes listed, *see also* Pt 6, Ch 6,2.10. In addition, the plans submitted for approval are to contain the enhanced scantling, together with the nominal thickness less the enhancement, adjacent and in brackets.

Section 7
Protective Coating in Water Ballast Tanks

7.1 Protective Coating in Water Ballast Tanks – PCWBT

7.1.1 It is recommended for all ship types that all salt water spaces having boundaries formed by the hull envelope are to have a corrosion protection coating applied.

7.1.2 If the Owner so wishes, a notation **PCWBT** 'Protective Coating in Water Ballast Tanks', will be entered in the *Register Book* to indicate that the ship's water ballast tanks are coated and that the coating remains efficient and well maintained. If the coatings have broken down, particularly at more critical areas, and no effort is being made to maintain the coatings, then this notation will be placed in parentheses, i.e. (**PCWBT**). In either case the date of the last survey will be placed in parentheses after the notation.

Section 8
Hull Condition Monitoring

8.1 Hull Condition Monitoring – HCM

8.1.1 Where an Owner adopts the LR Hull Condition Monitoring Scheme the notation **HCM**, 'Hull Condition Monitoring' will be entered in the *Register Book*.

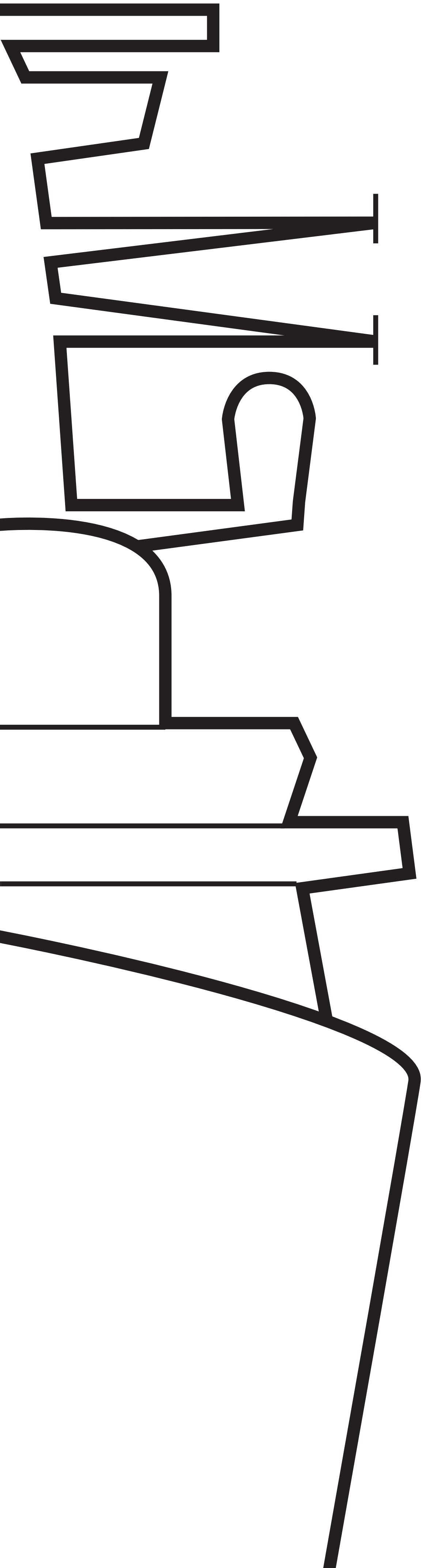
8.1.2 This notation will indicate that a computer software system for on-board recording of ship surveys is available aboard ship.

Section 9
Ship Emergency Response Service

9.1 Ship Emergency Response Service – SERS

9.1.1 This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship.

9.1.2 Where an Owner adopts this service, the notation **SERS**, 'Ship is registered with LR's Ship Emergency Response Service', will be entered in the *Register Book*.



Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 4*

Military design and special features

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Lloyd's Register

Chapter Contents

Volume 1, Part 4

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■ *Section 1* General requirements

1.1 General

1.1.1 This Section is aimed primarily at assessing structure such that it can resist the military loads imposed upon it, however it is essential in naval ship design to consider the effects an item of equipment or structure can have on a variety of parameters. For example a winch support and mount may adequately resist the forces imposed upon it during normal operation and absorb shock loads but have an unacceptably high noise or radar signature.

1.1.2 Chapter 1 gives guidance on some of the additional issues that the designer must consider in the design of a naval ship. Whilst it does not always give the definitive answer on these topics, it will help identify the impact of structural design on the subject. An example is radar signature reduction. The guidance gives the geometric properties to avoid but it will not give detail on radar absorbent coatings.

1.1.3 Information is classified in two types. Firstly, design guidance for which further approval has to be sought once a suitable standard is identified by the Naval Authority, and secondly, design requirements which have to be met as part of the ✠**100A1** notation or a specific notation such as **LA(N)**.

1.2 Plans

1.2.1 Plans are to be submitted showing the manner in which the requirements have been met and the location of the structure within the vessel for those features that have either a special notation or are required as part of the notation ✠**100A1** or ship type.

1.2.2 Details on the loadings applied to individual items, and by these items to the support structure are to be included. In some cases stiffness requirements will also need to be included, e.g. mast mounted equipment.

1.2.3 Plans, and where requested, calculations should be submitted for the following features as appropriate:

- Replenishment at sea arrangements.
- Aircraft and vehicle tie down arrangements.
- Movable decks, ramps and lifts.
- Masts and support arrangements.
- Towed array or towed body arrangement.
- Weapon recoil and thrust loadings.

1.2.4 Arrangements for the following features are to be included with the hull structural plans listed in Pt 6, Ch 2,2. In addition calculations are to be supplied where requested:

- Vehicle decks.
- Helicopter decks.
- Berthing.
- Docking loads.
- Beach landing or grounding.
- Holding down arrangements.

1.2.5 Plans and supporting calculations should be submitted for the following notations:

- External blast (**EB1, EB2, EB3, EB4**).
- Internal blast (**IB1, IB2**).
- Fragmentation (**FP1, FP2**).
- Small arms protection (**SP**).
- Under water explosion (Shock) (**SH**).
- Whipping (**WH1, WH2, WH3**).
- Residual strength (**RSA1, RSA2, RSA3**).

1.3 Signature

1.3.1 A naval vessel will generally require some form of signature control and the operational requirement will determine the extent to which this is necessary. Signature control can be achieved using a variety of methods both active and passive. This section deals with the passive methods that structure can influence.

1.3.2 With good structural design the signature of the vessel can be controlled to a certain degree with little cost. The methods listed in Table 1.1.1 can help achieve this.

1.3.3 It is beyond the scope of the Rules to provide further detail on signatures, however on request, Lloyd's Register (hereinafter referred to as 'LR') is able to provide information on suitable organisations who are able to provide specialist advice as necessary.

1.3.4 Special features notations for signature control will not normally be assigned. Some of the above features will form part of the Naval ship notation ✠**100A1 NS** and are detailed in Section 3. If requested by the Owner a descriptive note can also be assigned.

Table 1.1.1 Ship signatures

Signature	Simple methods of control using hull construction
Above water	
Visual	Camouflage paint
Infra-red	Careful positioning of exhaust outlets
Radar cross section	Structural shaping
Unintentional electro-magnetic emissions	Use of steel plating (Faraday cage)
Under water	
Self noise	Fairness of hull, low vibration
Radiated noise	Low vibration
Magnetic field	Non-ferrous materials Degaussing
Electric field	Attention to earth paths
Wake	Hull form, propeller design

1.4 Materials and welding

1.4.1 In addition to the requirements of Pt 6 Ch 2, ships having the following military distinction notations are to comply with the requirements of this section for the designated areas unless specified otherwise. The requirements apply to plates, stiffeners, fillet welds, butt welds and welded attachments:

- **EB1, EB2, EB3, EB4** Above water portion of the hull, superstructure and upper decks assessed against external blast requirements.
- **IB1, IB2** Blast bulkheads.
- **SH1, SH2** Hull envelope plating.
- **WH1, WH2, WH3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.
- **RSA1, RSA2, RSA3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.

1.4.2 Crack arresting strakes of minimum Grade E are to be fitted in the following locations, from $0{,}2L_R$ to $0{,}8L_R$, according to the notation assigned:

- **SH1, SH2** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **WH1, WH2, WH3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **RSA1, RSA2, RSA3** Sheerstrake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.

Where the hull envelope is made entirely from Grade D steel, crack arresting strakes of minimum Grade E need not be fitted in the specified locations.

1.4.3 Generally for joints between steels of different strength levels the welding consumable may be of a type suitable for the lesser strength.

1.4.4 For joints between steels of different toughness levels, the welding consumable is to be of a type suitable for the higher grade being connected.

1.4.5 The consumable used is to comply with the requirements of Table 1.1.2. Other grades of steel will be specially considered, but in general, the toughness in the upward vertical direction is not to be significantly less than that of the parent plate, measured in the direction of rolling.

Table 1.1.2 Welding consumable grade

Steel grade	Normal electrode grade	Military requirement grade
A	1	1
AH32	1Y	2Y
AH36	1Y	2Y
AH40	2Y40	2Y40
B	2	2
D	2	3
DH32	2Y	3Y
DH36	2Y	3Y
DH40	3Y40	3Y40
E	3	4
EH32	3Y	4Y
EH36	3Y	4Y
EH40	4Y40	4Y40

■ *Section 2* **Survivability**

2.1 General

2.1.1 Survivability is defined as the probability that a ship can remain operational to some degree following an attack. The elements of whole ship survivability are shown in Fig. 1.2.1. Survivability is divided into two main aspects:

- Susceptibility, the probability of a threat acquiring, reaching and detonating on a ship.
- Vulnerability, the probability that a ship will be able to survive a successful attack and operate at a certain level.

Survivability is normally calculated as the product of susceptibility and vulnerability. Recoverability is an important aspect as it has a significant influence on the vulnerability of the overall ship as a system. It can be defined as a measure of the ability of the ship to reach a particular level of operation higher than that immediately following the hit. A variety of levels of operation required following damage can be defined, *see* 2.2.

2.1.2 Generally there are four basic phases in the classification of naval ships with respect to survivability.

- Concept phase.
- Assessment phase.
- Build phase.
- Maintenance phase.

2.1.3 The **concept phase** is not normally part of classification and is a discussion between the Owner, Naval Authority, designer and those specialists able to perform the appropriate calculations. It is used to identify the potential threats, requirements for the ship structure, machinery and systems with respect to those threats.

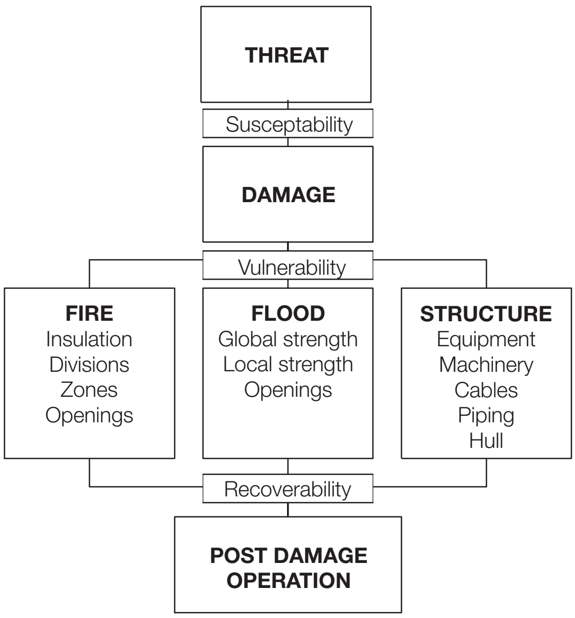


Fig. 1.2.1 Whole ship structural survivability

2.1.4 The **concept phase** will apply all of the elements shown in Fig. 1.2.1:

(a) Identification of the threat is first and this is usually determined by the Naval Authority for current and future threats. Several threats will be identified which affect the ship in a variety of ways, they may be under water or above water, far field, close in, or contact weapons. Typical threat groups are given in Table 1.3.1.

(b) The susceptibility is the ability of the threat to reach the ship and detonate and is a function of the capability of the threat, the ship's signatures and the ship's defence systems. Various computer codes and simulations are available for determining the susceptibility of a hull and the capability of weapon systems. Consideration should be given to the degradation of a threat by a ships defence systems.

(c) If a threat detonates, damage may result. The extent and amount of damage is a function of the vulnerability of the ship, *see* 2.2. A vulnerability assessment may be used to determine the consequences of the threat detonation. The consequences are likely to be in the form of fire flood and physical damage as shown in Fig. 1.2.1. The assessment tools used in the design stage for vulnerability analysis generally employ simple design formulae which are then verified during the assessment phase.

(d) The consequences of damage can be limited through recoverability, the ability to repair damage to structure, equipment and systems. This is mainly an operational matter though it will have an impact on ship design. Damage control operational procedures will make certain demands on structure and equipment.

2.1.5 It is beyond the scope of the Rules to provide further detail on the concept phase. However on request, LR is able to provide details of suitable organisations who are able to provide specialist advice as necessary.

2.1.6 The **assessment phase** looks in more detail at the vulnerability of the ship and uses explicit calculations to assess the capability of the ship based upon the relevant effects of threats such as blast pressure or fragment size. It is not necessary to define the actual weapon, just the consequences or effects of threats. A threat can produce a variety of effects, the manner in which the rules currently address these effects is detailed in Chapter 2. In naval ship classification, notations are used to donate that a calculation for a particular threat has been reviewed. Currently, these are concerned with structural aspects only, though some aspects of machinery are indirectly addressed through other notations such as propulsion machinery redundancy, **PMR**, steering gear machinery redundancy, **SMR** and fire safety, **FS**.

2.1.7 The **build phase** ensures that the requirements of the assessment phase are put in place onboard the ship. It is identical to the normal classification requirements for construction, installation and testing of structure and equipment under LR survey, verifying that the correct materials, welding fabrication and testing procedures are used.

2.1.8 The **maintenance phase** is applied by maintaining a ship in class through life. It verifies that the original standard to which the ship was built is maintained and that any new rule requirements are implemented. It also verifies that modifications to the ship do not compromise the integrity of the structure, equipment or systems.

2.1.9 It is the responsibility of the Naval Authority to ensure that each of the phases is implemented, to define the requirements that are to be met and advise the Owner on the manner in which particular threats can be dealt with.

2.2 Vulnerability

2.2.1 The resistance of a vessel to loadings from military threats can be described by the term vulnerability which is the probability that once hit by a specified threat a vessel will lose capability.

2.2.2 This chapter deals separately with the effects of a threat on the structure but when considering the total vulnerability of the ship it will be necessary to combine all the effects of a weapon detonation to determine the total damage to the ship as a system. This is normally done during very early in the design stage at a low level of complexity, *see* 2.1.4. Several computer codes are available to determine the consequence of weapon threats on the ship system.

2.2.3 The damage to a ship is likely to occur by three mechanisms; fire, flood and physical damage, *see* Fig. 1.2.1. The direct effect of threats on the ship's crew is not included in this section but some features such as shelter stations and NBC protection will reduce the risk. Indirect damage caused by the threat should also be considered and a vulnerability analysis can be used to site magazines such that they are offered the maximum protection.

2.2.4 The methods used to control the spread of fire will have an effect on structural design, materials, fire insulation, fire divisions and openings, and must all be considered. One method used to control the spread of fire is zones and some guidance on the philosophy and structural requirements are provided in Section 7. However the precise requirements for fire detection, protection and extinction are to be defined by the Naval Authority. Where this is examined by LR in accordance with Pt 1, Ch 2,3.9.10 a **FS** notation may be assigned. Other methods include the use of smoke tight boundaries, insulation and fire fighting systems.

2.2.5 The stability of a vessel and flooding following damage is not covered in this chapter. The stability standard, nominated by the Naval Authority, will define the extent of damage that the vessel is required to survive and remain stable. All structure and watertight closing appliances will need to be assessed to this level. Pt 3, Ch 1,5 defines how the minimum extent of watertight subdivision is to be determined. Pt 3, Ch 4 contains details on requirements for closing appliances. For such an extreme event as flooding, plastic type analysis is appropriate for watertight structure and this is recognised in the relevant rule requirements.

2.2.6 For the hull, the effect of the threat can be limited in two ways:

- Ensuring that there is adequate global strength f ollowing damage using a residual strength analysis. Where appropriate a whipping analysis may also be necessary.
- Ensuring that local structure can contain the threat or limit the damage. Individual items of structure can be hardened or strengthened in certain areas to achieve this.

2.2.7 Physical damage may occur to cables, piping, equipment and machinery, and other systems. The duplication or protection of these items is dealt with in Vol 2, Pt 1, Ch 2,4.8. Where protection is required, e.g. armour, the impact on the structural design of the hull is to be considered.

2.2.8 Different levels of vulnerability can be represented, as illustrated in Fig. 1.2.2. Each will have different acceptance criteria for the hull structure. For an internally detonating threat, the increasing levels can be visualised as a threat of increasing magnitude rather than increasing distance.

2.2.9 Level A is that, closer than which, the hull structure will fail due to the detonation of a threat. The failure can occur in a number of ways as detailed in Chapter 2. At this level the assessment will normally be performed using plastic criteria which will result in permanent deformation. The ship may no longer function effectively but it should remain afloat and not rupture or fail catastrophically.

2.2.10 Level B is that, closer than which, the majority of the ship's machinery and equipment is damaged such that it will not operate effectively and the ship can no longer continue to navigate. The hull must therefore not deform permanently and elastic assessment criteria may be necessary to determine the global strength of the hull (local deformation may be sustained).

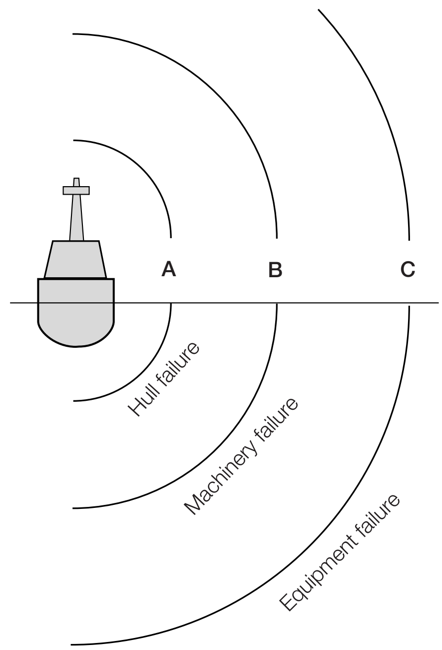


Fig. 1.2.2
Vulnerability contours for a given threat level

2.2.11 Level C is that, closer than which, the ship's weapon systems begin to fail and the vessel is no longer able to operate with full effectiveness. Normally the global and local criteria would be assessed against elastic criteria.

2.2.12 Levels B and C for underwater threats are primarily dealt with by adopting a suitable shock policy for the ship.

2.2.13 It is the responsibility of the Owner to decide the levels at which these should be set. In theory, they could be made to be coincident but this would provide little reserve within the vessel for recovery by damage control and repair. Conversely, they should not be set too far apart as this represents unnecessary armament and strengthening which is not effectively protecting the equipment and machinery from attack.

2.2.14 For an assessment of a threat which also produces effects on machinery, two structural calculations may have to be performed. One at the equipment level of failure using failure criteria that result in little or no deformation (plating only for example) and one approaching a structural failure level using ultimate strength or plastic collapse criteria. The requirements in Chapter 2 generally deal with ultimate strength or plastic criteria, the conventional rule calculations in Pt 6, Ch 2 and Chapter 5 set elastic failure criteria. For normal naval ship construction, the hull is usually able to withstand the threat level at which equipment and systems fail with little or no permanent deformation, though some check calculations may be necessary on critical areas.

■ *Section 3*
Military distinction notations

3.1 General

3.1.1 By its very nature a naval ship will be required to face and resist a variety of threats and it will be necessary to incorporate particular features to address those threats.

3.1.2 Some of the features required are already incorporated in the notation ✠**100 A1 NS**. However, where the operational requirement demands, additional or specific levels of performance, special features notations such as those listed in Pt 1, Ch 2,4 may be assigned showing protection against the effects of a particular threat.

3.1.3 Unless specifically requested these notations will be assigned at an appropriate level which will remain confidential to the Owner. It is the responsibility of the Owner to determine the threat levels suitable for their requirements. The agreed threat levels will not appear in the *Register Book* or be published in any other form. Only the notation ✠**MD** will be used to show that some military features have been incorporated and constructed in accordance with LR's *Rules and Regulations for the Classification of Naval Ships*.

3.1.4 A distinction is made between:

- levels of threat, describing the magnitude of the missile, torpedo, mine or bomb; and
- method of analysis which may be performed at differing levels of complexity.

3.1.5 In an effort to establish links between the different military loads, default levels of threat have been assigned. A distinction is made between levels of above water and under-water threats, certain ships may be at greater risk from one or the other depending upon their operational requirements. They are summarised in Table 1.3.1.

3.1.6 In addition to the hull class notations defined in Pt 1, Ch 2, ships complying with the requirements of this Chapter will be eligible to be assigned the additional class notations defined in Pt 1, Ch 2,2.1 and Ch 2,2.3 or descriptive notes as defined in Pt 1, Ch 2,2.6.

3.2 Above water threats

3.2.1 As described in Table 1.3.1 the external blast notation is normally independent of the internal blast and fragmentation notations as the threats that produce a survivable blast effect usually have a reasonable stand off. Typically, significant blast loading will arise from externally detonating threats such as far field nuclear at large stand offs and fuel air explosions at moderate stand offs. For an externally detonating conventional weapon, the blast will normally be insignificant but there will usually be a fragmentation threat. The external blast notation may also be independent of the residual strength notation unless the plastic deformation from an external blast renders certain structure ineffective with respective to global strength. For example a superstructure which contributes to longitudinal strength.

Table 1.3.1 Relationship between notations

	Above water weapons								Under water weapons			
	Small arms	Shell or projectile		Missile		Bomb			Mine or charge		Torpedo	
	Contact	Contact	Proximity	Contact	Proximity	Contact	Proximity	Far field (2)	Contact	Proximity	Contact	Proximity
SP	R	O										
FP		R	R	R	R	R	R					
IB		R		R		R						
EB			R		R		R	R				
SH									R	O	R	O
WH										R		R
RSA		O	O	R	O	R	R	R	R		R	

Symbols

R = Required threats to be considered in the absence of a specific requirement.
O = Optional threats to be identified by the Naval Authority and dependent on the characteristic of the threat

NOTE
1. It remains the responsibility of the Owner to determine the appropriate military notation and the appropriate levels of threat and analysis.
2. For nuclear threats, consideration should be given to NBCD requirements for structure, see Section 7, filtration and ventilation. The ability of the structure to screen an electromagnetic pulse should also be considered.

3.2.2 Usually, both internal blast and fragmentation will result from an internally detonating threat and are therefore linked, for example, a missile threat as shown in Table 1.3.1. For a particular threat it is recommended that both fragmentation and internal blast assessments will be made to the same level of threat for the structure adjacent to the point of detonation. Consideration should be given to the precise nature of the blast loading and fragmentation pattern of the threat.

3.2.3 If transverse bulkheads are used to limit the longitudinal spread of damage then the decks and side shell will probably be damaged such that a residual strength assessment is required to ensure that the global strength is not compromised. This should be to the same threat level as the internal blast threat. Longitudinal blast resistant bulkheads, box girders or service tunnels could be used to maintain the longitudinal effective material of the hull girder.

3.2.4 A residual strength assessment of the above water structure can be carried out for any threat level under any threat, independently of the other above water threat notations. This is because the ship may still retain function even though it has not been specifically armoured against the internal blast or fragmentation arising from such a threat. The residual strength notation is normally required for sea skimming missile threats that may remove significant areas of above water structure.

3.3 Under water threats

3.3.1 Shock enhancement should be aimed at providing ruggedness and to verify at a low level, equipment and system operation is maintained and at a higher level, equipment is retained and the hull does not rupture. Notation is currently confined to structure and concentrates on local damage that can be addressed by close attention to quality of construction and by adopting good constructional detail. Shock effects give rise to equipment and system damage. Shock is a different mechanism to whipping, therefore a whipping assessment will not generally be required to the same level of a shock assessment, though it may be necessary to check that the shock threat assessed will not have a significant whipping load. Residual strength assessments may be appropriate for shock threats depending on the extent of local damage.

3.3.2 Whipping is caused by proximity detonation of a charge that excites the main hull girder at a low-order (two node) natural frequency which may cause significant structural damage at a relatively low charge weight. Shock effects therefore may be relatively low order and it will not always be necessary to undertake a shock analysis. In addition a whipping analysis may not be necessary for threats which detonate on contact or for steel ships under 70 m in length. Due to the nature of whipping effects (usually the plastic collapse at a section of the hull), a residual strength calculation is not normally appropriate for a whipping threat because the damage from the direct shock is usually limited.

3.3.3 Residual strength assessments of under water threats are normally concerned with contact mines or torpedo impacts. These will remove a certain amount of hull structure the effect of which is to be assessed by the residual strength calculation. Shock or whipping threats will only require a residual strength notation where there are significant amounts of local deformation to the hull girder. Significant damage is defined as that which reduces the global strength below the design margins.

3.4 Analysis levels

3.4.1 In addition to levels of capability determined by the threat level specified, there are also different methods of assessment. The method of assessment will depend on three aspects:

- The level of the threat. At higher levels of threat, the requirements of the rules may become uneconomical or impractical and a more in depth analysis is required.
- Applicability of the rule formulations. If the threat level is outside the range of applicability of the rule formulations further analysis will have to be undertaken.
- Acceptance criteria, dependent upon whether the threat is to be assessed against elastic or plastic collapse criteria.

3.4.2 Three methods of assessment are shown in Fig. 1.3.1. In general the same threat level can be specified in each case however, it is the responsibility of the Owner to specify the correct levels to meet their specific requirements.

(a) The analysis of military loads can be most simply be assessed using the elastic model created for rule analysis. This will result in an acceptable but conservative solution.

(b) The next more complex method uses an elasto-plastic or ultimate strength model.

(c) Finally more complicated processes such as 3D dynamic analysis can be used to determine the loading for the elasto-plastic model. Normally this will be carried out for local areas of interest.

3.4.3 Once an ultimate strength model has been created for the appropriate sections along the hull it may be utilised for a variety of military notation calculations, as shown in Fig. 1.3.1(b).

3.4.4 The damage required for the residual strength calculation can be defined in a variety of ways for a variety of threats, collisions or groundings. Non-military damage is defined in Pt 6, Ch 4,4 and military damage by the damage radii in Pt 4, Ch 2,7 or specifically from external blast and vulnerability calculations. The results from a vulnerability analysis can be used for input to a variety of military notations and, in general, formal vulnerability assessments will be required for higher threat levels, *see* 2.1.4.

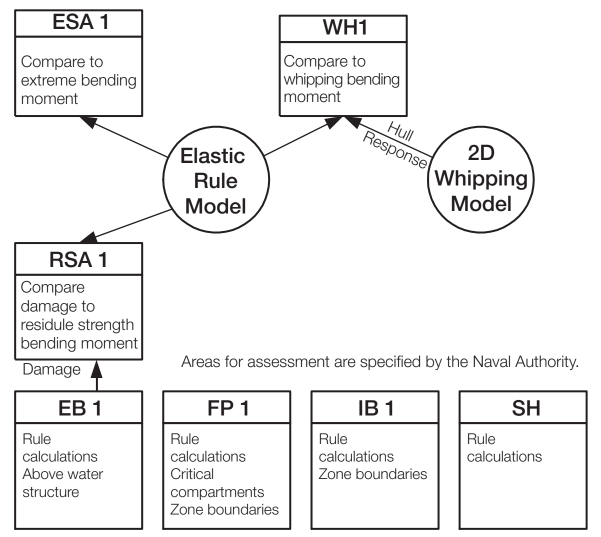


Fig. 1.3.1(a) Assessment methods 1

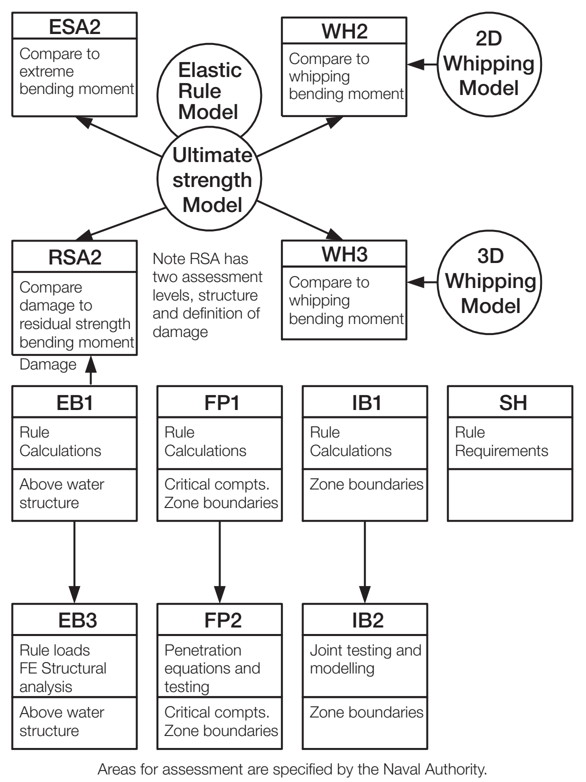


Fig. 1.3.1(b)
Assessment methods for higher threat levels

■ *Section 4* Military design guidance

4.1 Radar signature

4.1.1 All constructional details on the exposed surfaces of the hull and superstructures above the design waterline should be considered for their radar reflection properties.

4.1.2 Structure that presents three orthogonal internally reflecting surfaces to an incoming radar signal are to be avoided. Superstructure overhangs, sponsons and equipment mounts are particular problem areas.

4.1.3 Flare and tumble home as defined in Fig. 1.4.1 are to be used where possible on all vertical surfaces. The angle used should be greater than 6°.

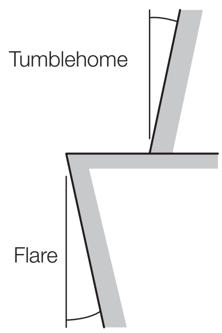


Fig. 1.4.1 Radar reflection

4.1.4 The use of lattice type masts and equipment supports should be avoided.

4.1.5 The use of conical structure should be avoided.

4.1.6 Consideration should be given to the effects of clutter on exposed weather decks and the use of radar absorbent materials both of which can significantly reduce the radar cross section.

4.2 Use of aluminium alloys

4.2.1 Due to the poor performance of aluminium alloys at high temperatures they are generally not to be used for items of main hull structure unless suitable insulation is arranged. Safety critical items such as life boat davits, ladders, fire main supports, emergency escape route bulkheads and floor plates, etc., are not to be constructed of aluminium alloys.

■ *Section 5* Military design requirements

5.1 RAS seating and support structure

5.1.1 The strength of seats and supporting structure is to be sufficient to withstand the forces imposed by the equipment for all possible operating conditions and loads from ship motions, *see* Pt 5, Ch 3,5.3. Design calculations are to be submitted.

5.1.2 The seating and supporting structure is to be tested in accordance with Naval Authority requirements. Care is to be taken to ensure that the test arrangements represent the actual magnitude and direction of loads, and that the loading is applied to all relevant parts of the supporting structure rather than local items only.

5.1.3 Guidance on the loads and requirements for replenishment at sea operations are given in Ch 2,9.2.

5.1.4 A sufficient deck area clear of projections and equipment suitably strengthened for impact loading is to be provided for the landing of stores and equipment.

5.1.5 RAS equipment is to be designed in accordance with the requirements of the Naval Authority, *see* Pt 1, Ch 2,2.2.6 and Vol 3, Pt 1, Ch 7.

5.2 Vehicle and equipment holding down arrangements

5.2.1 The strength and stiffness of the holding down arrangements and the supporting structure under is to be sufficient to withstand the forces imposed by the vehicle(s) and or equipment for all possible operating conditions and loads from ship motions, *see* Pt 5, Ch 3,5.4. The design calculations are to be submitted.

5.3 Masts and externally mounted sensors or equipment

5.3.1 Masts are to be of adequate strength and stiffness for the equipment they support. The design calculations are to be submitted.

5.3.2 The excitation of the mast by ship motions, machinery, propellers and equipment is to be specially considered and the designers calculations are to be submitted. In general, ship motions can be estimated from Pt 5, Ch 3,2 and the mast natural frequencies are not to be within a band ± 20 per cent of significant excitation frequencies. *See also* Pt 6, Ch 2,5.

5.3.3 Structure supporting radar or equipment critical to the operation of ship systems is to be of adequate stiffness to maintain the alignment of the equipment within the tolerance agreed with the manufacturer.

5.3.4 The mast should be designed and sited such that it produces minimum interference with the ships sensors and equipment.

5.3.5 Suitable access arrangements are to be provided inside the mast for maintenance of the structure and equipment. Provision is to be made for the drainage of water from all parts of the mast, both internal and external. Where applicable, protective coatings are to be applied in accordance with the requirements of Pt 6, Ch 6,2.6. In certain cases an increased corrosion allowance (e.g. at the mast base) should be considered.

5.3.6 Mast support arrangements are to be of suitable strength and stiffness and fully integrated into the hull or superstructure. The design calculations and arrangements are to be submitted.

5.3.7 For equipment distributed along the length of the ship, consideration is to be be given to the global stiffness of the ships' hull girder in relation to the alignment tolerances required for the equipment (increasing hull stiffness is not normally an efficient option).

5.3.8 High powered transmitting equipment where fitted is to be considered for the effects of electromagnetic influence on adjacent equipment and manned spaces.

5.4 Towed arrays, towed bodies and towing points

5.4.1 The support structure of towed systems is to be suitably integrated into the main hull structure. Any additional primary stiffening is to be extended for at least three frame spaces forward and aft of the equipment.

5.4.2 The towing point and associated equipment is to be located over a primary longitudinal girder and preferably supported by a transverse web frame. The designers calculations are to be submitted for the supporting structure using the 1,5 times the maximum breaking load of the cable.

5.4.3 Towed array handling equipment is to be designed in accordance with the requirements of the Naval Authority, *see* Pt 1, Ch 2,2.2.6. The seating of array handling equipment is to be adequately supported.

5.5 Crane support arrangements

5.5.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

5.5.2 The scantlings of masts and derrick posts, intended to support derrick booms, conveyor arms and similar loads, and of crane pedestals are to be designed in accordance with the requirements of the Naval Authority, *see* Pt 1, Ch 2,2.2.6. When submitting plans for the proposed foundation, the design calculations are to be submitted.

5.5.3 Deck plating and underdeck structure are to be reinforced under masts, derrick posts or crane pedestals, and where the deck is penetrated the deck plating is to be suitably increased.

5.5.4 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the ship's heel and trim. The designers calculations are to be submitted.

5.5.5 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

5.5.6 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

5.5.7 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

■ *Section 6* Design guidance for magazines

6.1 General

6.1.1 The requirements for the design, construction and maintenance of magazines are to be in accordance with the regulatory requirements specified by the Naval Authority. Recognized regulatory requirements should generally be in line with the requirements of this Section.

6.1.2 A statement of magazine requirements should be defined and should to include:

(a) Armaments requirement; listing the munitions and materiel to be carried in magazines. Identifying the items which can or should be co-located and those which must be stored separately or separated. Any special requirements for the storage of particular items are also to be listed including:
   (i) environmental conditions;
   (ii) shock protection requirements;
   (iii) conductive deck coating requirements;
   (iv) rocket reaction loads.
(b) Construction materials requirement; describing the permissible materials or required alternatives for magazine structures and munition stowages.
(c) Incident mitigation requirement; describing the measures to be adopted to mitigate the effects of the firing of stored munitions or rockets.
(d) Magazine Labelling requirement; describing the required labels and their locations.
(e) Fluid Systems requirement; describing the operating fluids and operating pressures of all fluid systems within the magazine boundaries.

6.1.3 The postulated credible accident requirements are to be based on the results of a hazard evaluation with regard to the magazine, munitions stowage, handling and transportation.

6.1.4 Hazards that should normally be considered include:

(a) Hostile action, a detonation of a threat munition leading to fragmentation and, or shock or blast loading on the munition. A vulnerability analysis as described in Ch 1,2 may be used to identify the risk.
(b) Fire, from hostile action or peace time incident.
(c) Terrorist attack or sabotage.
(d) Handling incidents, from dropping the munition or impact by handling equipment.
(e) Aircraft incident on the flight deck.
(f) Ship collision or grounding.
(g) Electro magnetic interference (EMI) and electrostatic effects (ESD) causing accidental initiation.
(h) Nuclear effects.
(j) Air conditioning failure.

6.1.5 The hazard assessment should be undertaken from two points of view. Firstly, a threat external to the munition causing an incident within the magazine. The aim of protection or mitigation being to prevent the blast, heat radiation, bullet or fragment reaching the munition. Secondly the threat of the initiation or detonation of the munition. The aim of protection being to prevent communication between magazines or a sympathetic reaction and to reduce the damage volume, hence minimising the effect on integrity and survivability of the ship. In addition to 6.1.4, the following specific threats to the munition, should be considered:

(a) 12,7 mm bullet attack.
(b) Sympathetic reaction.
(c) Liquid fuel fire.
(d) Fragment attack.
(e) Slow heating.
(f) Propulsion motor firing.

6.1.6 The risk to magazines and consequently their location within the ship' hull is to be determined by a vulnerability assessment, *see* Ch 1,2.

6.1.7 Magazines, designated danger areas and compartments adjacent to magazines are to be fitted out electrically with the requirements specified by the Naval Authority in accordance with National standards.

6.1.8 Munition securing and handling equipment is to be in accordance with requirements of the Armaments Requirement or, with special consideration, LR's LAME Code. Explosive stores are to be classified and stowed in accordance with the armament requirement, *see* 6.1.2.

6.1.9 In general, both a primary and secondary ammunitioning route are to be provided for munitions from their embarkation point to their dedicated permanent stowage. In addition, primary and secondary routes should be provided from the permanent stowage to ready use lockers, magazines or the point of use. Handling equipment along these routes is to be in accordance with the requirements of 6.1.8.

6.1.10 Ready use magazines shall not be used for the permanent stowage of munitions. They are to comply with the requirements of this section for the appropriate magazine type.

6.2 Definitions

6.2.1 Munitions are a complete device (e.g. missile, shell, mine, demolitions store, etc., charged with explosives, propellant, pyrotechnics, initiating composition or nuclear, biological or chemical material), for use in conjunction with offensive, defensive, training, or non-operational purposes, including those parts of the weapon systems containing explosives.

6.2.2 Integral magazines are those which are bounded by the elements of the main hull structure. They are specifically designed and constructed for the safe permanent stowage of the main outfit of designated munitions defined in the armaments requirement, *see* 6.1.2.

6.2.3 Independent magazines are those that are non integral, portable magazines greater than 3 m^3 and the requirements for integral magazines are to be applied where applicable.

6.2.4 Small magazines are compartments opening off the upper deck which are of shape and size which does not permit walk-in and where the contents are handled from outside. Small magazines are to be specifically designed and constructed for the safe permanent or ready use stowage of munitions defined in the armaments requirement, *see* 6.1.2.

6.2.5 Magazine lockers are magazines less than or equal to 3 m^3, designed and constructed for the safe stowage of explosive stores for which in built magazine facilities have not been provided. They are to be free standing, surrounded by an air gap such that they do not have an adjacent compartment.

6.2.6 Magazine boxes are non-integral, portable magazines with a capacity less than or equal to 3 m^3 and capable of being jettisoned overboard.

6.2.7 Pyrotechnics lockers are to comply with the requirements for small magazines, magazine lockers or boxes as appropriate.

6.2.8 Class A fire divisions are those divisions formed by bulkheads and decks which comply with the requirements of IMO resolution MSC 61 (67) *Fire test procedures code*, Annex 1, Part 3.

6.2.9 RATTAM is Response to ATTack on AMmunition and is protection provided to ship magazines to counter credible peacetime attacks.

6.2.10 Flash is a product of an explosion embracing transient flame and associated pressure wave and the electromagnetic wave.

6.2.11 Designated danger areas are compartments and spaces not fitted out specifically for the stowage of munitions, but where munitions are occasionally present.

6.2.12 NEQ is the net explosive quantity and equal to the mass of the explosive content.

6.2.13 Burning is defined as a Type V reaction which is the least violent type of event. The energetic material ignites and burns non propulsively. The case may split open non violently, or weaken significantly to allow mild release of combustion gasses. Case closure may be dislodged by the internal pressure.

6.2.14 Flame screens are a single screen of corrosion resistant wire of 144 meshes per cm^2 using wire of 0,3 mm diameter. Alternatively they can consist of two corrosion resistant wires of 64 meshes per cm^2 using wire of 0,4 mm diameter, spaced between 12 mm to 38 mm apart.

6.3 Arrangement of magazines

6.3.1 Magazines are to be located to afford the maximum physical protection from damage emanating from all credible sources. In **NS1** and **NS2** ships, magazines are to be separated laterally and vertically by the greatest possible extent.

6.3.2 If possible magazines are to be sited below the waterline with smaller ready use magazines located near to the point of use.

6.3.3 Integral magazines and small magazines containing munitions above 57 mm diameter or propellant are not to be sited adjacent to compartments of high fire risk listed below:

(a) Main machinery spaces including diesel generator compartments, gas turbine compartments.
(b) Galleys.
(c) Switch boards or electrical control rooms.
(d) Tanks containing liquids with a flash point lower than 60°C or with a temperature above 32°C.
(e) Compartments containing liquid oxygen.
(f) Fuel, petrol, oil or lubricant pump spaces.

6.3.4 Access is not permitted from any of the spaces defined in 6.3.3, to the magazine.

6.3.5 For ships where the above arrangement is completely impracticable the magazine is to be separated from the high risk space by a minimum 600 mm wide cofferdam and constructed of steel or an A-30 fire division. Cofferdams are to comply with the requirements of Pt 3, Ch 2,4.10.

6.3.6 No gasoline or pressurised bottle stowage is to be within a 6 m radius of any magazine or locker.

6.3.7 Integral magazines and small magazines containing munitions of diameter less than 57 mm may be situated adjacent to the compartments listed in 6.3.3 provided they are separated by an A-30 fire division.

6.3.8 Integral magazines and small magazines containing munitions may be sited adjacent to the following compartments of moderate fire risk provided that are separated by an A-30 fire division.

(a) Auxiliary machinery spaces including pump rooms air condition plant spaces, refrigeration compartment spaces and hydraulic compartments not containing flammable hydraulic fluids.
(b) Service spaces, including laundries and workshops.
(c) Uptakes and downtakes.
(d) Hangars, docks and vehicle decks.
(e) Paint, flammable, battery and acid stores.
(f) Tanks or compartments containing independent tanks, of liquids other than sea or fresh water.

6.3.9 Generally, magazine lockers are to be sited on a weather deck, be surrounded by an air gap of at least 300 mm on all sides and protected from direct sunlight by fitting solar cladding over top and sides with an air gap of at least 25 mm.

6.3.10 Magazine lockers are not to be situated in any of the compartments listed in 6.3.4 and 6.3.8.

6.3.11 Magazine lockers or boxes designated to contain RATTAM susceptible munitions must have suitable RATTAM protection, *see* Ch 2,4, or be sited such that they can not come under direct attack from small arms.

6.3.12 Within magazines arrangements are to be made to ensure that all munitions, including those in transit packaging, are safely stowed and suitably restrained in their stowage. Munitions identified in the armaments requirement as susceptible to underwater shock are to be certified to meet the specified shock protection requirements. Separate stowage is to be provided for each type of explosive except where specified by the armaments requirement, *see* 6.1.2.

6.3.13 Certain munitions will also require magazines to provide suitable electro-magnetic screening and earthing arrangements in accordance with the armaments requirement, *see* 6.1.2.

6.3.14 Generally magazine boxes are to be sited on a weather deck with an air gap of at least 300 mm between the box and the deck or surrounding deck houses. They are to be located in a position suitable for jettisoning of the contents and capable of remote release.

6.3.15 Detonator lockers may be sited as agreed with the Naval Authority in nominated dry secure storerooms provided the total NEQ of the detonators does not exceed 1 kg per storeroom. Where the total NEQ of the detonators to be embarked exceeds 1 kg, stowage is to be provided either by siting detonator lockers in a dedicated detonator magazine, sited below the waterline, or in a number of dry secure storerooms.

6.3.16 Detonators lockers are not to be sited in compartments subject to; temperatures above 32°C, excessive vibration or which contain flammable liquids, solvents, mixed paints, acids or any other material liable to spontaneous combustion.

6.3.17 Detonator Lockers are not to be sited less than 100 mm from the compartment boundary, measured from the bulkhead plating and are not to be secured to the ships side. The free air distance between Detonator Lockers is not to be less than 300 mm. Where 300 mm cannot be achieved, they may be permitted with 100 mm air gap, provided that an 8 mm steel plate is fitted between each locker.

6.3.18 Primary and secondary ammunitioning routes are to be as direct as possible, commensurate with safety. They are to be sheltered as far as practicable, from the physical and electromagnetic environment. The routes are to enable the munitions to be moved rapidly from the dump area to the permanent stowage, and, where required, to its ready use stowage or point of use, with the minimum amount of man power. The secondary route is not to be common with the primary route as far as is practicable.

6.4 Structure

6.4.1 Magazine lockers and magazine boxes are to be constructed of steel greater than 3 mm thickness. Other material may be accepted as identified in the construction materials requirement, *see* 6.1.2.

6.4.2 Integral magazines, small magazines or portable magazines are to be constructed of steel greater than 8 mm. Other material may be accepted as identified in the construction materials requirement, *see* 6.1.2.

6.4.3 Where munitions are stowed in silos or canisters, precautions are to be taken to prevent the most severe response of explosive store to bullet attack causing a sympathetic reaction in adjacent stores greater than burning.

6.4.4 The scantlings of magazine boundaries below the vertical limit of watertight integrity are to be determined from the general plating and stiffening equations in Pt 5, Ch 3,5.8 for deep tank or watertight bulkheads or the equivalent quasi static pressure caused by the postulated credible accident whichever is greater. Scantlings of magazines above the vertical limit of watertight integrity are to be determined using the equivalent quasi-static pressure caused by the postulated credible accident.

6.4.5 The scantlings of magazines with a free flood arrangements are to be designed using the general plating and stiffening equations of Pt 6, Ch 2,2 as appropriate with the pressure;

$P = 11{,}2h$ kN/m^2

where

h = height from the top of the outflow to the part of structure being considered, in metres.

6.4.6 Arrangements are to be made to ensure that the magazine is not pressurised by the free flood or sprinkling arrangements and adequate automatic air escapes are to be arranged that vent to atmosphere. The automatic air escapes are to be designed to operate at 1,38 kN/m^2 or the elastic design capability of the magazine structure whichever is less.

6.4.7 Pressure relief or blast vent plates are to be arranged to ensure that for the postulated credible accident, the pressure within the compartment does not rise above 80 per cent of that which would cause elastic failure of the bulkheads or decks. An equivalent quasi-static pressure may be used to determine the elastic failure pressure of the bulkhead, calculations are to account for the response time of the venting system. In the absence of a specific requirement, the venting arrangements for magazines containing rocket motors, should be capable of venting the gases produced by the ignition of a single round or munition.

6.4.8 Vent plates are to be capable of withstanding the force imposed by sea, weather or personnel where appropriate, *see also* Pt 3, Ch 4.

6.4.9 Venting is to be direct to atmosphere or via a dedicated vent trunk. The cross sectional area of the trunk is not to be less than that required for the vent plate. The number of obstructions and bends within the vent trunk is to be kept to a minimum. Where they exist, their effect on the flows in the vent trunk is to be assessed. Vent trunks are to be as short as possible. When a large venting area is required more than one plate is to be fitted.

6.4.10 Where the use of aluminium and, or GRP is defined in the construction materials requirement, in the boundaries of magazines, suitable fire protection is to be arranged on both sides of the boundary. The protection is to be such that the temperature response of the structure due to postulated credible accidents, from inside the magazine and out, does not exceed that which will cause significant reduction in the strength properties of the material.

6.5 Environmental conditions and ventilation

6.5.1 The temperature of the magazine is to be maintained at the environmental conditions required by the armaments requirement, *see* 6.1.2. Generally munitions are to be stored at temperatures greater than 7°C and less than 35°C with a relative humidity between 30 and 70 per cent. Munitions with propellant are to be maintained below 32°C.

6.5.2 Compartments containing magazine lockers are to comply with the requirements of 6.5.1.

6.5.3 The air conditioning may be recirculatory if confined to the ventilation of magazines only. If the magazine is to be ventilated with other compartments then the magazine is to vent to atmosphere. In general high fire risk and high value compartments should not share ventilation with magazines.

6.5.4 Where a magazine or magazine complex may require to be manned, fresh air make up, via the Air Filtration Unit is to be provided.

6.5.5 Emergency life support apparatus is to be sited in magazines where personnel are required to be permanently working.

6.5.6 Temporary arrangements are to be provided to ensure that in the case of a system failure the temperature does not exceed 40°C in 12 hours.

6.5.7 All magazine ventilation valves are to be capable of being operated both locally and remotely. The operating positions are to be sited as follows:

(a) Where the magazine is sited within the citadel, both the local and remote operating positions are to be sited inside the citadel.
(b) Where the magazine is outside the citadel, operating positions may be either inside or outside the citadel.
(c) Local and remote operating positions are to be sited in a readily accessible place with unrestricted access.
(d) Remote operating positions are to be sited in a place which allows operation without risk to personnel from the hazard in the magazine or at the local operating position. The remote position is to be separated from the local position by at least one watertight sub-division and must not be sited in an adjacent compartment.

6.5.8 Ventilation trunking is to be airtight to the same pressure as the magazine.

6.5.9 Air conditioning and ventilation systems are to be designed to maintain watertight integrity, flash and flame tightness, anti sabotage and NBCD integrity.

6.5.10 In vessels which are designed to meet low magnetic signatures, trunking may be of a composite material as required by the construction materials requirement, *see* 6.1.2.

6.5.11 Firesafe valves are to be fitted in both supply and exhaust trunking, external to the magazine boundary and near the bulkhead.

6.6 Detail arrangements

6.6.1 All stowages, racks and associated fittings are to be constructed of steel unless otherwise specified in the construction materials requirement, *see* 6.1.2.

6.6.2 A minimum free air space of 60 mm is to be maintained between stowages and bulkheads and stowages and the deck.

6.6.3 Rockets are to be arranged such that their efflux does not impinge on any munitions within the magazine. Additional protection is to be provided to prevent efflux from burning through the magazine boundary. The rocket is to be adequately secured to satisfy the armaments requirement, *see* 6.1.2, in the event of motor firing.

6.6.4 Following a hazard assessment, *see* 6.1.4 to 6.1.6, internal protection may be necessary to reduce the effects of sympathetic reactions in magazines. If a munition is assessed as vulnerable, mitigation shall be adopted. Any of the following methods may be used singularly or in combination:
(a) Fracticide bars.
(b) Metal shielding.
(c) Water barriers.
(d) Plastic or ceramic barriers.
(e) Armour.

6.6.5 Mitigation as required by 6.6.4, shall be afforded to 'sensitive' munitions to prevent accidental initiation and sympathetic reaction of munitions temporarily sited in weapon parks.

6.6.6 Clear labelling of all magazine openings and equipment is to be maintained in accordance with the magazine labelling requirement, *see* 6.1.2.

6.6.7 The fitting of electrical equipment and cabling to the boundaries of magazines is to be avoided as far as practicable. Where this is unavoidable for equipment, items may be fitted to the boundary provided that there is a stand off of at least 60 mm to assist boundary cooling and minimise heat transference in case of fire.

6.6.8 To facilitate handling of munitions and detonators, sloping ladders are to be fitted to compartments containing magazines and on ammunitioning routes. Where practicable, consideration should be given to the provision of chutes.

6.7 Openings

6.7.1 Doors, hatches, hoists or other openings in ships structure are not to be placed in way of efflux. Where this is not practicable, they are to be flameproof when closed.

6.7.2 Openings in the magazine and lockers such as doors, hatches and escape scuttles are to be of equivalent strength to the surrounding structure.

6.7.3 The openings of magazines containing munitions with propellant and magazine openings to areas where there is a risk from flash such as the hanger, weather deck or an ammunitioning route are to be either watertight, gastight or flashtight in accordance with Fig. 1.6.1. Suitable earthing of flash tight openings is to be arranged.

6.7.4 Accesses to magazines are to be fitted with suitable security arrangements. In general, openings are to be capable of being secured from the inside and fitted with external locks. Emergency escapes are to be opened from the inside only.

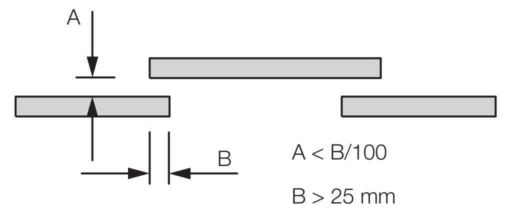


Fig. 1.6.1 Flash tight openings

6.7.5 Locking arrangements on all magazines and lockers are to be designed to prevent the possibility of entry by removing the hinge pins.

6.8 Piping, cabling and electrical systems

6.8.1 All equipment in magazines is to be intrinsically safe, *see* Vol 2, Pt 10, Ch 1,13.3. The installation of electrical equipment and cables in magazines is to be minimised as far as possible subject to operational requirements. Where it is necessary to install electrical equipment or cables they are to comply with the requirements of an appropriate standard defined by the Naval Authority. Equipment and cables are to be constructed from non flammable materials.

6.8.2 Lighting is to be operated from outside the space.

6.8.3 All apparatus fitted in magazines is to be capable of being isolated on all poles from any source of electrical energy. The preferred method of isolation is by means of a multipole switch.

6.8.4 Switches and marker plates stating the method of isolation are to be sited outside the magazine in a prominent position on the access route to the main door.

6.8.5 Generally, only services which are required for equipment in the magazine are to penetrate boundaries of the magazine.

6.8.6 Services that cross the boundary of the magazine which are vulnerable to sabotage are to have anti-sabotage arrangements to prevent ingress of foreign bodies or fluids. In general, all vent trunks, exhaust outlets, air inlets and automatic air escapes are to be fitted with grilles and where appropriate, goose necks.

6.8.7 Cabling other than for magazine equipment should not pass through the magazine. Degaussing, echo sounder and sonar transducer cables may pass through the magazine provided that the run is continuous, i.e. without junction boxes. Where cables are exposed to the atmosphere outside the magazine they are to be enclosed in steel conduit within the magazine to protect against the effects of electro magnetic pulse (NEMP).

6.8.8 Air and hydraulic systems used within magazines are to be low pressure systems only. Non-flammable hydraulic fluid is to be used.

6.8.9 Electrically controlled handling machinery may be fitted in magazines provided continuous earth monitoring is provided in the control circuits of the machinery.

6.8.10 All protective metal guards for apparatus and cabling as well as the apparatus itself must be effectively earthed. Conduit is to be electrically continuous and bonded to earth to form an effective shield.

6.9 Fire protection

6.9.1 Integral and small magazines are to be fitted with a spray system capable of rapid reaction, with manual and automatic activation.

6.9.2 Spray systems for integral magazines may be activated by heat detectors (and smoke). Each of the detectors is to be independently capable of activating the system. Generally a minimum of three heat detectors are required in a magazine. They are to be distributed across the deckhead taking into account the layout of the magazine and relationship of the boundaries to the potential risk from adjacent compartment or area.

6.9.3 Small magazines may be activated by a thermal detector head, for example a quartz bulb, provided that the system is primed at all times and an isolating valve is located adjacent to and outside the compartment.

6.9.4 Missile canisters in silos may require high pressure water supply for local spray and deluge, in addition to the spray system required in 6.9.2 for drenching the exterior of the canister.

6.9.5 The spray system is to be capable of delivering 30 litres/m^2/min. Large compartments should be fitted with several independent spray systems covering separate areas.

6.9.6 Spray heads are to be arranged within magazines so that all stowages and boundaries are covered when sprayed. The designers calculations for hydraulic flow should be made available.

6.9.7 Spray systems are to have a local and remote control station. The local and remote control position is to be provided with a manual override facility. The remote operating position is to be separated from the local position by at least one deck or a main watertight bulkhead. Where practicable, all remote operating positions should be sited in one location. For magazines containing International maritime dangerous goods (IMDG) class 1.1 munitions, (substances and articles that have a mass explosion hazard) where the NEQ is greater then 500 Kg an emergency operating position is to be located on the weather deck.

6.9.8 Spray systems are to be fed from two separate sections of the ship's water supply.

6.9.9 Magazine lockers are generally to be fitted with flood and drainage systems. The flood system is to be operated by a manual control adjacent to the locker but at least 5 m away or 3 m if suitably screened and fed from a pressurised water supply.

6.9.10 Heat and smoke detectors are also required to activate audible and visible alarms both locally and remotely. The smoke and heat detectors are to be part of a type approved fire detection alarm system. In addition the heat detector operating temperature is not to be greater then 30°C above the maximum anticipated deck head temperature.

6.9.11 Compartments adjacent to magazines are to be fitted with smoke or fire detectors.

6.9.12 Locking arrangements are to be fitted to all spray, flooding, drain valves and cocks with the exception of Pneumatic spray control valves.

6.9.13 Magazines are to be provided with fire extinguishers commensurate with risk classification, size and type of vessel. Generally one extinguisher should be fitted on the inside and one on the out side of the magazine.

6.9.14 Other areas at risk such as weapon lifts, transfer passages or weapon preparation areas are to be fitted with similar fire protection systems to the magazine.

6.9.15 Designated danger areas (DDA) where munitions are handled such as hangars, flight decks, docks and RAS points are to be fitted with manually operated spray systems and or hose points, commensurate with the risk classification and type of vessel.

6.9.16 Munitions assessed as vulnerable to fuel fire are not to be stored adjacent to any aircraft, motor transport or fuelling points of either.

6.9.17 Magazines are to be coated with fire resistant paint and the deck covering is to be non spark and non slip. Any requirements for a conductive deck area and personnel will be identified in the armaments requirement, *see* 6.1.2. Where there is a conducting deck requirement an anti static precaution notice is to be displayed.

6.10 Testing

6.10.1 Magazines are to be tested in accordance with the gas tight requirements of Pt 6, Ch 2,5.

■ *Section 7*
Design guidance for nuclear, biological and chemical defence

7.1 General

7.1.1 The arrangements of hull structure for nuclear, biological and chemical defence (NBCD) are to generally be in accordance with the requirements of this Section. The final design and arrangements are to be in accordance with the requirements of the Naval Authority. Where specifically requested, LR can undertake the inspection and certification of NBCD arrangements or gas tight integrity, *see* Vol 1, Pt 6, Ch 6,6.8.

7.1.2 The subdivision of the ship for NBC defence is achieved by the provision of zones which minimise the consequences of an attack. The zone boundaries provide protective barriers to resist the spread of primary and secondary weapon effects.

7.1.3 The number and location of zone boundaries and distribution of systems within those zones is best determined by carrying out a vulnerability analysis as detailed in Section 2.

7.1.4 The effect of zones on, and requirements for damage control should also be considered. This is best assessed by testing the zone arrangement with a series of 'what if' damage scenarios. A good zone arrangement will aid damage control.

7.1.5 An effective NBC defence is to comprise of three distinct phases:

- Monitoring and detection by the provision of systems to detect the presence of and to identify the threat both outside the ship and within the zones.
- Protection of the ship and crew, using a pressurised citadel and zones with gas-tight boundaries and airlocks. Protection is also achieved with the filtration of air drawn into the ship and enclosing machinery intakes and exhausts.
- Decontamination of spaces within the ship is achieved using a suitable ventilation and filtration system. Decontamination of the ship itself is largely achieved using pre-wetting systems. For the crew and equipment, cleansing stations can be used.

7.2 Definitions

7.2.1 A citadel is the gastight envelope of the hull and superstructure. It consists of a group of interconnecting compartments enclosed by a gas-tight boundary with the independent systems necessary to provide a toxic free area free from any NBC hazard. Large ships may have sub-citadels or more than one citadel.

7.2.2 A zone is a smaller group of compartments within the citadel with some or all of the independent systems necessary to provide a toxic free area that is free from any NBC hazard.

7.2.3 An airlock is a compartment with two doors between the toxic free area and the source of the NBC hazard or cleansing station. Airlocks are normally purged with clean air to allow personnel to pass from one area to another without contaminants entering the toxic fee area.

7.2.4 A cleansing station is a group of compartments suitably arranged and equipped whereby NBC decontamination of personnel and materials can take place.

7.2.5 Individual protective equipment is the personal clothing and equipment required to protect an individual from NBC hazard. It normally consists of a protective suit and respirator.

7.3 NS1 and NS2 ship requirements

7.3.1 The requirements of this section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. Provision is to be made within the layout and design of the ship for the compartments required for NBC defence. As a consequence they are to be considered from a very early stage in the design and in consultation with the Naval Authority, Owner, designer and LR.

7.3.2 Unless otherwise required by the Naval Authority, the citadel is to be divided into a minimum of four zones each with a maximum length of 30 m. The combined length of adjacent zones is to be greater than $0,3L_{WL}$ and less than $0,5L_{WL}$. The zone boundaries are to coincide with main transverse watertight bulkheads and extend from the keel to the highest superstructure deck.

7.3.3 A suitable pressure above atmospheric is to be maintained inside the citadel and zones. Zones with a higher risk of contamination are to be maintained at a lower pressure than the adjacent zones but higher than atmospheric. For example those containing machinery spaces with ventilation to atmosphere open during NBC conditions.

7.3.4 For NS1 ships at least three cleansing stations are to be provided in separate zones. For NS2 ships at least two cleansing stations are to be provided in separate zones. They are to be located so that safe and direct entry is possible from the weather deck. One cleansing station is to be located close to the medical complex with access for stretcher borne casualties.

7.4 NS3 ship requirements

7.4.1 The requirements of this section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. As a consequence they are to be considered from a very early stage in the design and in consultation with the Naval Authority, Owner, designer and LR.

7.4.2 For NS3 ships it may be impractical to provide zones and a citadel. In this case NBC protection is to be provided by either individual protective equipment or sanctuaries.

7.4.3 Sanctuaries may be integral or temporary compartments on board the ship and are to be provided with an airlock, cleansing station and ventilation systems similar to that of a zone.

7.4.4 If individual protective equipment is provided arrangements are to be made to ensure that operation of the ship is possible such that it can reach a suitable place of refuge. For example, crew provisions, equipment and compartment accesses are to be suitable for persons wearing individual protective equipment.

7.5 Zones

7.5.1 The boundaries of zones are to be gastight and are to be tested in accordance with Pt 6, Ch 6,6.8. Ventilation and trunking is not to pass through zone boundaries.

7.5.2 Each zone is generally to be provided with a total air conditioning system. All air entering the citadel is to pass through NBC filters. These filters may be bypassed when the ship is not in a threat situation.

7.5.3 Consideration is to be given to the provision of independent services in each zone for the following systems:
(a) Electrical power generation and distribution.
(b) Chilled water cooling.
(c) Fire pumps, piping and hydrants (including pre-wetting).
(d) Bilge pumps, piping and discharge.
(e) Internal communications.
(f) Machinery or damage control surveillance or control.
(g) Compressed air.
(h) Emergency crew support.
(j) Smoke clearance arrangements.
(k) Air start arrangements in the appropriate zones.

7.5.4 At least two airlocks to the weather decks are to be provided in each zone. Access between zones are to be fitted with airlocks. Consideration is to be given to providing gas-tight connections adjacent to this access for the provision of the services listed in 7.5.3.

7.5.5 Consideration should be given to the use of materials that do not emit toxic fumes.

7.6 NBC hardening

7.6.1 In determining the layout and design of the ship consideration should be given to the hardening of the ship to improve it's capability in an NBC environment.

7.6.2 All external compartments and equipment not included in the citadel should be sealed or designed such that residual contaminants cannot be trapped.

7.6.3 All access for operation and maintenance of equipment should be designed for personnel wearing individual protective equipment.

7.6.4 Shelters are to be provided deep within the ship for the temporary protection from radiation of the crew during nuclear attack.

7.6.5 Command and control centres should ideally be sited such that they are afforded the maximum protection against radiation from nuclear attack. All essential equipment should be designed to resist incident nuclear radiation (INR) and nuclear electro-magnetic pulse (NEMP).

7.7 Structural requirements

7.7.1 The scantlings of all gastight zone, citadel and airlock boundaries are to be capable of withstanding two times the maximum differential pressure that can occur in service and the scantlings are to be calculated in accordance with the relevant sections of Pt 6, Ch 3. Gas-tight boundaries are to be tested in accordance with Pt 6, Ch 6,6.8.

7.7.2 All openings in gastight boundaries are to be fitted with gastight closing appliances and tested in accordance with Vol 1, Pt 6, Ch 6,6.8 and are to be of equivalent strength to the structure in which they are placed.

7.7.3 Watertight and weathertight closing appliances may be considered gas-tight if a pressure greater than atmospheric is, and can be maintained inside the zone, citadel or airlock.

■ *Section 8*
Design guidance for the reduction of radiated noise underwater due to sea-inlets or other openings

8.1 General

8.1.1 The number of underwater openings should be kept to a minimum.

8.1.2 To aid in the reduction of underwater radiated noise, sea tubes and/or boxes are to be provided for each sea water hull inlet or outlet. Where a number of openings are adjacent, consideration should be given to fitting a common plenum chamber with a single opening in the outer bottom. Care must be taken to avoid resonance of the chamber.

8.1.3 The outside of all underwater openings is to be flush with the surrounding hull plating. Particular care is to be taken to provide smooth surface on the inside of all sea-tubes and discharges.

8.1.4 For sea openings required to be blanked, a smooth mating face surrounding the sea tube on to which the mating flange of the blank can sit is to be provided.

8.1.5 Adequate protective coating and cathodic protection should be considered at the interface of the valve and sea tube.

8.1.6 No underwater opening, at a level lower than the deep design draught, is to be fitted within 6 m of the aftermost part of the aft sonar dome.

8.1.7 Wherever possible, gratings or anti-sabotage bars fitted to underwater openings are to be arranged across and aligned with the flow of the water past the ship so as to minimise turbulence. They should be deep in section and have well radiused edges.

■ *Section 1*
General requirements

1.1 General

1.1.1 This Chapter contains design requirements that have to be complied with as part of ✠**100A1** classification, ship type or a special notation such as **IB**.

1.1.2 Where significant regions of the hull structure are rendered ineffective by the threat under consideration, a residual strength calculation is to be carried out to verify the capability of the remaining structure.

1.1.3 For structure designed in accordance with the appropriate sections of this chapter the following notations will be assigned. The level of threat and notation will remain confidential to the Owner and Lloyd's Register (hereinafter referred to as 'LR') unless requested otherwise.

- **EB** for external blast assessment.
- **IB** for internal blast assessment.
- **FP** for fragmentation protection.
- **SP** for small arms protection.
- **SH** for assessment against underwater explosion (shock).
- **WH** for whipping assessment
- **RSA** for a residual strength assessment (*see* Pt 6, Ch 4,4).

1.1.4 The notations that are applicable for a particular ship are to be agreed between the builder or designer, Owner, Naval Authority and LR as defined in Vol 1, Pt 4, Ch 1.

■ *Section 2*
External blast

2.1 General

2.1.1 Structures and their response to air blast loadings, can be considered to fall into two categories:

- Diffraction-type structures.
- Drag-type structures.

2.1.2 In a nuclear type explosion, the diffraction-type structures would be affected mainly by diffraction loading and the drag-type structures by drag loading.

2.1.3 Large flat sided structures, with few openings, will respond mainly to diffraction loading because it will take an appreciable time for the blast wave to engulf the structure and the pressure differential between front and rear exists during the whole of this period. A diffraction-type structure is primarily sensitive to the peak overpressure in the shock wave to which it is exposed.

2.1.4 If structures are small, or have numerous openings, the pressures on different areas of the structure are quickly equalised; the diffraction forces operate only for a very short time. The response of this type of structure is then mainly due to the dynamic pressure (or drag forces) of the blast wind. This is typical of masts and funnels. The drag loading on the structure is determined not only by the dynamic pressure but also by the shape of the structure. The drag coefficient is less for rounded or streamlined structures than for irregular or sharp edged structures.

2.1.5 The relative importance of each type of loading in causing damage will depend upon the type of structure as well as the characteristics of the blast wave.

2.2 Threat level determination

2.2.1 Ships complying with the requirements of this Section will be eligible for the notation **EB1**, **EB2**, **EB3** or **EB4** as defined in 2.3.

2.2.2 External blast loading can come from a variety of threats the two main ones are far field from nuclear or fuel air type threats and near field from detonation by close in weapon systems. This part of the rules is concerned only with the far field explosions.

2.2.3 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

2.3 Notation assessment levels and methodology

2.3.1 Design to withstand increasing levels of blast pressure needs to employ increasing sophistication and complexity of analysis method if the structure is to be kept lightweight.

2.3.2 An **EB1** assessment method may utilise the simple design methodology suggested in 2.8 for structural assessment. The design criteria should ensure that the structure behaves in an elastic perfectly plastic manner with small displacements when subjected to the proposed blast level.

2.3.3 An **EB2** assessment method may utilise an extension of simple design methodology suggested in 2.8 to look at the elasto-plastic behaviour for the structural assessment. The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.4 An **EB3** assessment method should employ a failure criterion based on an elasto-plastic methodology which considers the following structural responses:

- Local response of the plating, here the plating can be represented as a 2-D plate strip and a large displacement, elasto-plastic dynamic response analysis carried out using a beam-column approach.
- Local bending response of stiffened panels, the preferred model will be to evaluate the non-linear dynamic response of a single stiffener with an attached strip of plating modelled as a beam-column with the appropriate boundary conditions under blast pressure.
- A lumped parameter model can be employed to look at 'overall sidesway' response of a ships superstructure.

The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that are attached or adjacent to the structure.

2.3.5 An **EB4** assessment method should employ a full non-linear analysis using finite element methods to predict the structural response. Using this methodology it is assumed that the ship must survive, this implies the need to retain primary hull structural integrity, water and gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.6 For **EB3** and **EB4** notations, the assumptions made for initial deformations are to be submitted. Where these differ for normal ship building practice, the details are to be recorded on the approved plan.

2.4 Definitions

2.4.1 Atmospheric pressure P_o is to be taken as 101,3 kN/m^2.

2.4.2 The dimensions of superstructure blocks are given in Fig. 2.2.1.

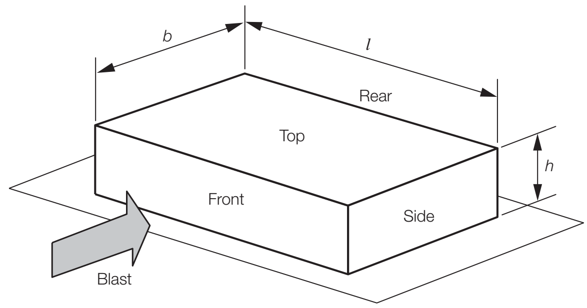


Fig. 2.2.1 Superstructure definitions

2.5 Blast pressure loads

2.5.1 For explosions of different magnitude, the range at which the peak blast incident and dynamic pressures occur can be scaled using the following equation:

$$D_i = D_n \left(\frac{1000}{W}\right)^{1/3}$$

where

D_i = incident distance
D_n = distance at which the pressure occurs, in metres
W = equivalent weight of TNT for the explosive, in kg.

2.5.2 Similarly for weapons of a different magnitude, the duration t_{p+} of a blast can be scaled using the scaling equation:

$$t_i = t_n \left(\frac{1000}{W}\right)^{1/3}$$

where

t_i = incident duration
t_n = duration the pressure occurs, in seconds
W = equivalent weight of TNT for the explosive, in kg.

2.5.3 When a pressure shock front strikes a solid surface placed normal to the direction of shock travel there is an instantaneous rise In pressure above that of the shock front itself. The total pressure referred to as the reflected pressure is given by:

$$P_r = 2P_i (7P_o + 4P_i)/(7P_o + P_i) \quad \text{kN/m}^2$$

when $P_i << P_o$ (small charge at large standoff) P_r may be taken as $2P_i$ similarly when $P_i >> P_o$ (large charge at short range) P_r may be taken as $8P_i$

where

P_i = peak blast incident overpressure in kN/m^2 from Fig. 2.2.3.

2.5.4 The reflected pressure, P_r can be assumed to diminish linearly until it reaches the stagnation pressure P_s at time t_s where

$$t_s = 3d/U \quad \text{seconds}$$

where

d = is the lesser of h or $l/2$ in metres, *see* Fig. 2.2.1
U = shock front velocity in m/s
$= U_o \sqrt{1 + 6P_i/7P_o}$

U_o = speed of sound in air in m/s
= $332 + 0{,}6T_o$
T_o = ambient air temperature in °C.

2.5.5 The passage of the blast is immediately followed by a transient 'blast wind' that exerts a supplementary dynamic pressure which is given by:

$q_i = 2{,}5\,(P_i^2/(7P_o + P_i))$ kN/m^2

where

P_i = peak blast incident overpressure in kN/m^2 from Fig. 2.2.3

The duration of the dynamic pressure t_{q+} can be determined from Fig. 2.2.3.

2.5.6 The stagnation pressure P_s is determined for the front of the superstructure block by:

$P_s = P_i + C_D\,q_i$ kN/m^2

and for the top, sides and rear by

$P_s = P_i - C_D\,q_i$ kN/m^2

where

P_i = peak incident pressure from Fig. 2.2.3
q_i = the dynamic pressure from 2.5.5
C_D = the drag coefficient of the structure from Table 2.2.1.

Table 2.2.1 Drag coefficients

Structure	Drag coefficient, C_D
Ship sides	+1,0
Front face	+1,0
Top and sides	
0–170 kN/m^2	+0,4
170–340 kN/m^2	+0,3
340–930 kN/m^2	+0,2
Masts and funnels	+0,75

2.5.7 For the top and sides of the superstructure the peak pressure will occur at time t_t which is given by:

$t_t = b/U$ seconds

where

b = superstructure breadth in m, *see* Fig. 2.2.1
U = shock front velocity in m/s, *see* 2.5.4

2.5.8 For the rear of the superstructure the peak pressure will occur at time t_r which is given by:

$t_r = b/U + 4d/U$ seconds

where

d = is the lesser of h or $l/2$, in metres, *see* Fig 2.2.1
b = superstructure breadth, in metres, *see* Fig 2.2.1
U = shock front velocity, in m/s.

2.5.9 Pressure distributions for the faces of the superstructure block are given in Fig. 2.2.2, together with the overall pressure acting on the block which is obtained by subtracting the forces on the rear face from those on the front.

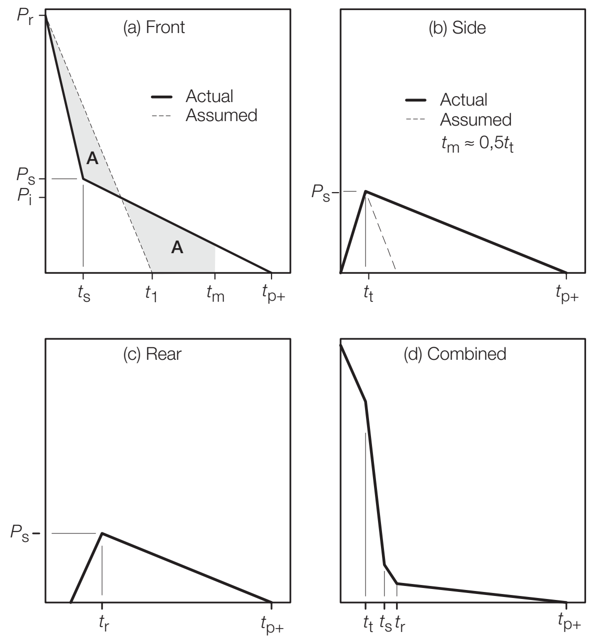


Fig. 2.2.2 Pressure distribution

2.6 Nuclear threats

2.6.1 An atmospheric nuclear explosion is most likely to occur at some height above ground level at a location known as ground zero, which may be optimised to produce maximum damage effects. The blast wave is reflected from the surface and at a certain distance from ground zero, primary reflected waves combine to form a vertical 'mach' front or stem that propagates outwards from ground zero with diminishing intensity. The peak blast incident over pressure P_i can be determined from Section 2.3.

2.7 Fuel air pressure loads

2.7.1 In general a structure designed to resist a moderate degree of nuclear blast will also have a reasonable resistance to fuel air threats and calculation are not normally required.

2.7.2 Where there is a risk of fuel air explosions, and for ships for which there is no nuclear threat position required, consideration needs to be given to the blast wave characteristics of such explosions, *see also* 3.1.7.

2.7.3 The effects of temperature on the material of the structure due to fuel air threats are to be considered using the structure surface temperature.

2.8 Conventional explosive pressure loads

2.8.1 Blast waves caused by free field explosions in air are dependent upon the mass shape and type of explosive, the distance from the target and the height of the burst. As blast waves travel through air, rapid variations occur in pressure, density, temperature and particle velocity.

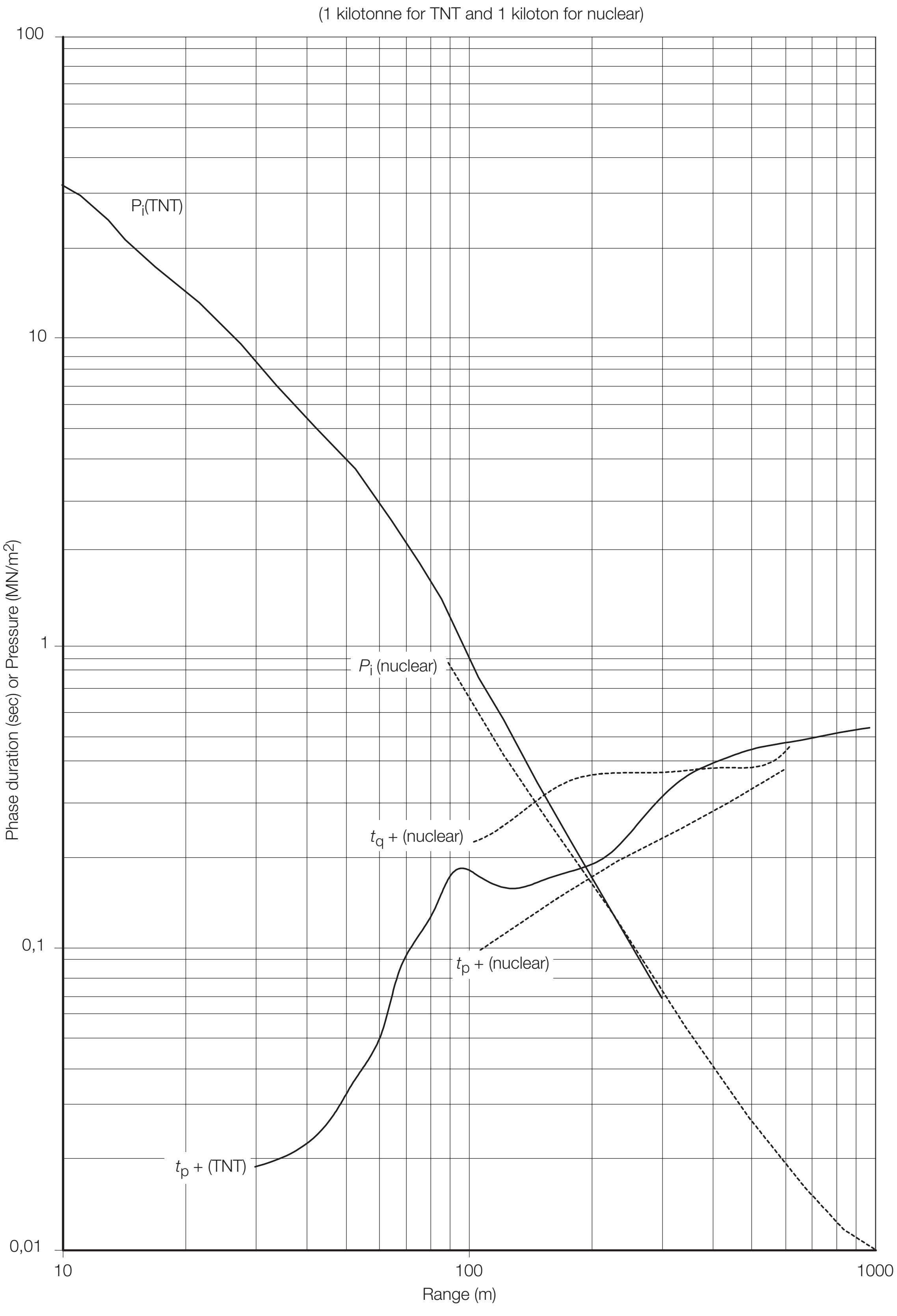


Fig. 2.2.3 Blast parameters for TNT and nuclear explosions

2.8.2 For a given high explosive of an equivalent TNT mass at a direct distance from the target Section 2.3 can be used to determine the blast parameters.

2.9 Structural assessment

2.9.1 The rules for the **EB1** and **EB2** structural assessment are based on the assumption that the structure can be idealised as a single degree of freedom system. They assume that there is no significant loading on the superstructure or ships' sides at the time of the blast. In cases where there are significant lateral loadings or concentrated point loads or fluids, the natural frequency and strength of the structure will be specially considered.

2.9.2 The acceptance criteria based contained in this section assume that the structure is loaded beyond it's elastic limit but not such that significant deformations result.

2.9.3 For plating the thickness is not to be less than:

$$t = \sqrt{\frac{f_{DLF}\, P_p\, l\, s^2}{6 f_\sigma\, \sigma_o\, (s + f_p\, l)}} \quad \text{mm}$$

where

l = the length of the plate panel, in metres

s = width of the panel, in mm (short span length)

σ_o = yield stress of the material, N/mm^2

f_p = plate aspect ratio factor, *see* Table 2.2.2

f_σ = stress factor

= 1,3 for $\sigma_o \leq 300$ N/mm^2

= 1,2 for $\sigma_o > 300$ N/mm^2

P_p = the peak pressure P_r for the front of the superstructure, or P_s for the top sides and rear, as defined in 2.5, in KN/m

f_{DLF} = dynamic load factor to be determined from Pt 6, Ch 2,6:

for superstructure front and ship sides using a linearly decreasing load with initially:

$t_1 = P_r\, t_s / P_s$ seconds

if t_m determined from Pt 6, Ch 2,6 is greater than 1,1 $P_r\, t_s/P_s$ then f_{DLF} is to be recalculated such that:

$$t_1 = t_s + \frac{P_s}{P_r}\left(t_p - t_m\,\frac{(t_{p+} - t_m)}{(t_{p+} - t_s)}\right) \text{ seconds}$$

For superstructure top, sides and rear using a triangular load with:

$t_1 = 2t_t$ seconds

$t_1 = 2t_r$ seconds as appropriate.

where

P_r = peak reflected pressure as defined in 2.5.3

P_s = stagnation pressure, as defined in 2.5.6

t_m = time at which maximum deflection occurs

t_{p+} = positive blast pulse duration

t_s = corresponding time at stagnation pressure, P_s

Table 2.2.2 Plate factors

Aspect ratio (A_R)	f_p
1,0	1000
0,9	916
0,8	858
0,7	817
0,6	775
0,5	750
<0,5	750

2.9.4 The minimum edge through thickness area of the plate is not to be less than:

$$A_\tau = \frac{1}{100 s\, \tau_o}\left(6 f_{p1}\, t^2\, \sigma_o \left(s + f_p\, l\right) + f_{p2}\, P_{tm}\, l\, s^2\right) \text{ cm}^2$$

where

t, σ_o, l, s are given in 2.9.3

τ_o = shear yield stress in N/mm^2

P_{tm} = Pressure at the time of maximum displacement, t_m, in kN/m^2 based on assumed pressure distribution

f_{p1}, f_{p2} = shear load factors, given in Table 2.2.3.

Table 2.2.3 Plate shear factors

Aspect ratio s/l	short span side s		long span side l	
	f_{p1}	f_{p2}	f_{p1}	f_{p2}
1,0	0,18	0,07	0,18	0,07
0,9	0,16	0,06	0,20	0,08
0,8	0,14	0,06	0,22	0,08
0,7	0,13	0,05	0,24	0,08
0,6	0,11	0,04	0,26	0,09
0,5	0,09	0,04	0,28	0,09

2.9.5 The stiffener and plate combination is considered to be satisfactory if the plastic modulus of the beam plate combination is greater than:

$$Z_p = \frac{f_{DLF}\, P_p\, l\, s\, l_e}{f_{bz}\, f_\sigma\, \sigma_o} \text{ cm}^3$$

where

P_p, f_{DLF}, f_σ, σ_o are given in 2.9.3

Z_p = plastic section modulus of the stiffener and attached plate, in cm^3

l_e = effective length of the beam, in metres

l = the length of the beam, in metres

f_{bz} = beam support factor

= 12 for fully fixed

= 8 for simply supported

s = spacing of the beams, in mm.

2.9.6 The maximum elastic deflection given by:

$$\delta_x = 10^5 \frac{f_{DLF}\, P_p\, l\, s\, l_e^3}{f_{bd}\, E\, I} \text{ mm}$$

is not to be greater than

$$\delta_{max} = \frac{1000 l}{115} \text{ mm}$$

where

P_p, f_{DLF}, s, l and l_e are given in 2.9.3

I = second moment of inertia cm^4

f_{bd} = beam support factor

= 384 for fully fixed

= 76,8 for simply supported.

2.9.7 The shear area of the stiffener web is not to be less than:

$$A_\tau = \frac{1}{100\tau_o}\left(\frac{f_{s1}\, f_b\, Z_p\, \sigma_o}{1000 l_e} + f_{s2}\, P_{tm}\, l\, s\right) \text{ cm}^2$$

where

Z_p, σ_o, l_e, l, s are given in 2.9.3

τ_o, P_{tm} are given in 2.9.4

f_{s1}, f_{s2} = shear load factors, given in Table 2.2.4.

Table 2.2.4 Beam shear factors

Beam type	Location	f_{s1}	f_{s2}
Simply supported	Both ends	0,39	0,11
Fixed ends	Both ends	0,36	0,14
Simple and fixed	Fixed end	0,43	0,12
	Simple support	0,26	0,19

2.9.8 Direct calculations or analyses based on the elastoplastic or plastic response of structure using a dynamic load factor or finite element approach will be specially considered. The designers' calculations are to be submitted for approval.

2.9.9 In addition to the assessment of plating and stiffeners, the global capability of superstructure and above water structure are to be assessed. The designers' calculations are to be submitted.

2.10 Design considerations

2.10.1 To minimise the effects of external blast, protrusions from the superstructure are to be kept to a minimum.

2.10.2 Re-entrant corners are to be avoided, where this is impractical they are to be covered by a blast deflecting plate, or be constructed such that the included angle between orthogonal faces is to be as large as possible.

2.10.3 Where the clear air gap between superstructure blocks is less than $0{,}1L_R$, the interaction under external blast loading will be specially considered.

■ *Section 3*
Internal blast

3.1 General

3.1.1 Internal blast is defined as that which occurs from detonation of a high explosive from a hostile weapon or detonation of a ship's own ammunition inside the hull envelope. In an internal explosive loading situation the loading on a boundary can be characterised by a series of decaying reflected pressure wave (blast impulses) followed by the rapid formation of a slowly decaying static pressure (Quasi static pressure QSP) as shown in Fig. 2.3.1.

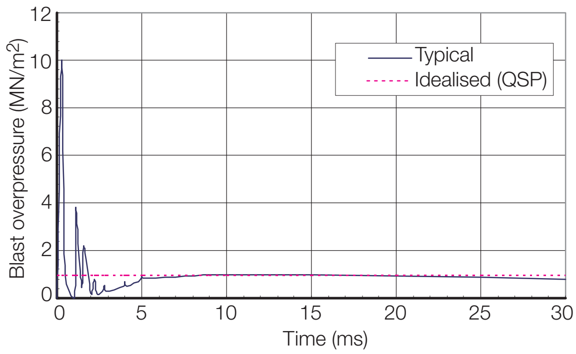


Fig. 2.3.1 Typical blast pressure time history

3.1.2 The magnitude of the initial blast impulse is related to the distance from structure under consideration to the explosion. The reflections are a function of the compartment geometry. The QSP is dependent on the compartment volume with the rate of decay related to the vent area.

3.2 Threat level determination

3.2.1 The threat protection levels for a given vessel should be determined through a vulnerability analysis against customer specified threat weapons. In the absence of such a study the following levels may be used as a guide:

- Level I Watertight bulkheads at $R_{4N} \geq 1$ and zone bulkheads at $R_{4N} >= 1$
- Level II Watertight bulkheads at $R_{4N} \geq 1{,}5$ and zone bulkheads at $R_{4N} > 2$
- Level III Watertight bulkheads at $R_{4N} > 3$ and zone bulkheads at $R_{4N} > 3$

R_{4N} is the normalised blast resistance 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead.

3.3 Notation assessment levels and methodology

3.3.1 The Rules are aimed at limiting the spread of blast damage to compartments adjacent to that directly affected by the explosion. For an explosion where the ratio of charge size to compartment volume is small, it may be possible to limit the damage to the affected compartment.

3.3.2 Ships complying with the requirements of this section will be eligible for the **IB1** notation. Where further analysis or testing are used to determine the blast resistance of the structure an **IB2** notation may be assigned.

3.3.3 For the **IB2** notation, the assumptions made for initial deformations are to be submitted. Where these differ from normal ship building practice, the details are to be recorded on the approved plan.

3.3.4 There are specific scenarios such as fuel air explosions within aircraft hangers where the internal blast wave characteristics will need to be specially considered on request.

3.4 Materials

3.4.1 For level III protection all plate bulkhead materials are to have a sulphur content less than 0,01 per cent. This may be achieved by the specification of through thickness properties in accordance with the requirements of Pt 2, Ch 3,8.

3.4.2 Consideration should be given to the use of austenitic electrodes for fillet welding of ferritic materials subject to high strain loading. In selecting the filler material, consideration is to be given to the material's proof strength and elongation; the 0,2 per cent proof stress of the filler material as welded is to match the strength of the ferritic parent steel plate, and the elongation to failure is to be as great as possible. Care should be taken to ensure that coatings are maintained as far as practicable. Where such materials are in wet or immersed areas, special attention is to be given to corrosion protection and the selection of a material that is not prone to chemical or electro-chemical attack. Details of the weld procedure are to be submitted for approval.

3.5 Quasi static pressure

3.5.1 Structural failure can be caused by either the impulsive loading or the dynamic loading imparted by the combined blast waves and QSP. Normally if the weapon is sufficiently large to cause failure by impulse it will also fail under a dynamic loading assessment based on a step function to the QSP level. For the purposes of general design the step function to the QSP level assessment can be used as the loading criteria to determine failure. Safety or mission critical areas should be specially considered.

3.5.2 The actual threat level used in the calculation and areas of the ship to be protected are to be specified by the Owner and will remain confidential to LR.

3.5.3 The QSP can be determined from the following:

$$P_{qs} = 2{,}25\,(W_e/V)^{0{,}72} \times 10^3 \quad \text{kN/m}^2$$

where

P_{qs} = quasi static pressure, in kN/m^2
W_e = weapon equivalent weight of TNT, in kg
V = free compartment volume, in m^3.

3.6 Structural resistance

3.6.1 The blast resistance for a given bulkhead material, thickness and joint style can be determined as a proportion of 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead using the following formula based on a combination of explosive tests and analytical techniques:

$$R_{4N} = (K_j + K_m)\, t/l$$

where
R_{4N} is the normalised blast resistance 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead
K_m is the material type factor, *see* Table 2.3.1
K_j is the joint type factor, *see* Table 2.3.2
t is the thickness of steel, in metres
l is the short span length, in metres.

Table 2.3.1 K_m material type factor

Steel grade	K_m
A, D, E, AH32, AH36	0
DH32, EH32	86
DH36, EH36	196

Table 2.3.2 K_j joint type factor

Joint style	K_j	Note
Normal fillet weld	625	Valid up for $t_{bh} \le 8$ mm
Full penetration weld	665	Valid for $t_{bh} \le 12$ mm
Austenitic fillet weld	701	Valid for $t_{bh} \le 6$ mm
NOTE Values of K_j up to 1200 can be achieved using blast resistant bulkhead designs.		

3.6.2 The primary mode of failure for bulkhead structures is through the edge connection. Alternatives to the basic fillet weld have been assessed and incorporated in the joint type factor presented in Table 2.3.2.

3.6.3 Alternative joint types may be used but are to be categorised using a dynamic joint test and blast assessment. For novel designs a further large scale controlled blast test of the proposed arrangement is to be tested. LR can provide details of the test and analysis requirements on request.

3.7 Bulkhead arrangements

3.7.1 Piping that passes through the bulkhead is to be fitted with expansion pieces either side of the bulkhead. In addition, piping and other penetrations are to be arranged at the edges of the bulkhead where the relative movement is less as shown in Fig. 2.3.2.

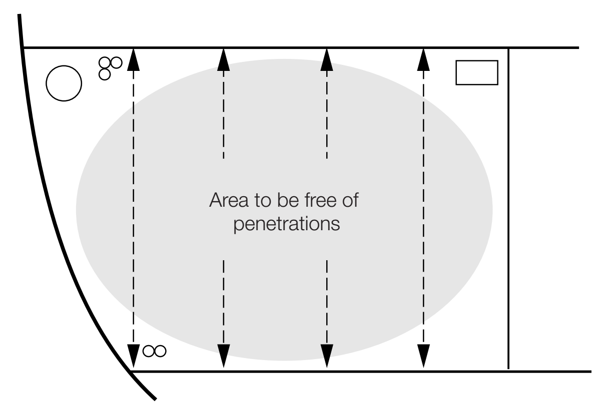


Fig. 2.3.2 Blast bulkhead penetrations

3.7.2 Bulkhead attachments are to be kept to a minimum and designed for good dynamic performance.

3.7.3 The strength of doors if fitted will be specially considered. Steps are to be taken to prevent their detachment from or pushing through the surrounding structure.

3.7.4 Consideration should be given to the use of flexible collars around deep girder penetrations through the blast bulkhead to allow relative movement but retain water-tight or gas tight integrity.

■ *Section 4* Fragmentation protection

4.1 General

4.1.1 This section does not deal with the loss of structural strength due to material perforation. It is only concerned with fragmentation protection of equipment and personnel within critical compartments and potentially critical pipe and cable runs.

4.1.2 Fragment and small arms penetrators can be stopped by the use of structure designed to prevent penetration, either through the use of increased thickness of normal structural materials, suitable siting of compartments, addition of armour (non-structural) materials, or even the use of armour material that can take structural loads.

4.1.3 The rules give design data based on fragment penetration equations for three representative threats. The selection and use of fragment penetration equations or computer modelling for other threats will be considered provided they are carried out by a competent body which has relevant experience and employs recognised procedures.

4.1.4 For fragmentation protection to be effective, materials within the ship forming part of the ship's equipment and outfit shall be of a type that is not prone to the generation of secondary fragments or 'splinters'. Materials such as wood, brittle plastics and brittle cast materials is not to be used in protected compartments. Where the use of such materials is essential, consideration may be given to the use of bonded splinter-retaining membranes.

4.1.5 RATTAM is defined as the response to attack on ammunition and describes protection fitted externally to the ship to prevent the penetration of particular threats which may cause damage, principally to magazines. Similar protection may also be fitted to protect other critical compartments, both are covered by the **SP** notation.

4.2 Threat level determination

4.2.1 The threat may be classified as either small arms fire or fragments from the casing of shells or warheads ('shrapnel' or 'splinters') capable of perforating the ships' structure and thus causing damage to equipment or casualties amongst personnel.

4.2.2 Three levels of protection are shown in Table 2.4.1. They are from a combination of internal and externally deto-nating threats. Alternative levels will be considered in accordance with 4.5.2.

Table 2.4.1 Fragment threat types

Level	Typical threat origin	Fragment weight (g)	Initial fragment velocity (m/s)
I	Aircraft fired 30 mm high explosive (HE) cannon shell	up to 1 g	less than 1250
II	Proximity detonating 105 mm Artillery round	up to 15 g	less than 1250
III	Sea Skimming (SAP) missile	up to 55 g	less than 1400

4.2.3 The actual threat level and type used in the calculation and the areas of the ship to be protected are to be specified by the Owner and will remain confidential to LR.

4.2.4 The Level I threat is assumed to detonate on impact with the ship's structure in the act of which it will penetrate the outer skin of the vessel. Fragmentation protection will reduce the risk of fragments penetrating additional compartments. The ends, internal sides and decks of critical compartment are in general to be fitted with protec-tion, an example of which is shown in Fig. 2.4.1(a), *see also* 4.3.2. The outer skin of the ship may be strengthened to resist the shell in accordance with the requirements for the **SP** notation, however it will usually require a significant amount of armour.

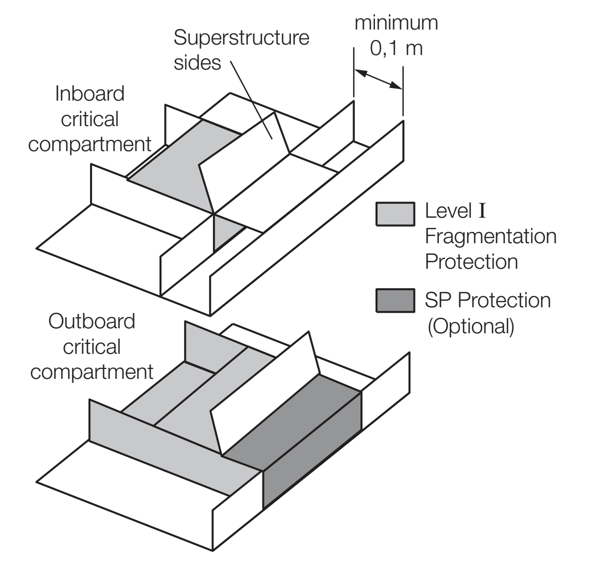


Fig 2.4.1(a) Level I arrangement

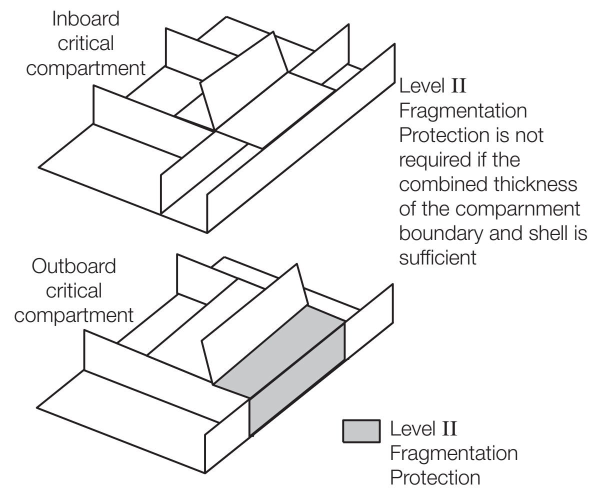


Fig. 2.4.1(b) Level II arrangement

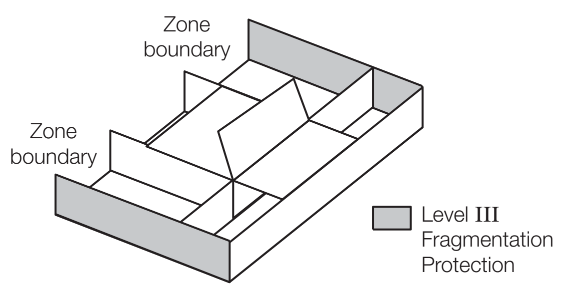


Fig. 2.4.1(c) Level III arrangement

4.2.5 Level II considers a threat posed by an externally detonating shell. Strengthening is, in general, to be fitted to the external skin of the ship to protect the critical internal spaces, an example of which is shown in Fig. 2.4.1(b), *see also* 4.3.2. For this level of protection a stand off distance for the weapon is to be specified by the Owner.

4.2.6 The Level III threat is a generic weapon based on a sea skimming anti-ship weapon with a semi armour piercing, (SAP) warhead that detonates within the hull. Fragmentation protection is intended to reduce the risk of fragments penetrating additional compartments. The considerable amount of protection required will normally mean that protection is only fitted at zone boundaries to limit the longitudinal spread of fragments. *See* example in Fig. 2.4.1(c) and also 4.3.2.

4.2.7 The examples given in Figs. 2.4.1(a) to (c) show a compartment immediately under the main deck with deck-house over subject to a side-on attack. Where the critical compartment is fitted directly below an external deck, in a deckhouse or the threat is directly above the compart-ment, protection is to be arranged using the principles given in examples in Figs. 2.4.1(a) to (c).

4.3 Notation assessment levels and methodology

4.3.1 The fragmentation protection **FP1** and **FP2** notations are assigned for ships which have protection fitted to resist fragments from the casing of a shell or warhead. The small arms protection, **SP** notation is assigned for ships fitted with protection to resist the penetration of small arms fire into the hull. For ships where the fragmentation resistance is carried out using the Tables and graphs of this section an **FP1** notation is assigned. Where fragmentation testing or analysis are used to determine the fragmentation resistance required a **FP2** notation is assigned.

4.3.2 The pressure produced by Level I threat is such that an **IB** notation is not required. The Level II threat is external and of a level such that an **EB** notation will not be required. A Level III threat will require the effect of the internal blast pressure on the structure to be considered and **IB** and **RSA** notations will generally be required.

4.4 Information required

4.4.1 For each threat level it will be necessary to identify the critical compartments requiring protection, plus the critical pipe and cable runs where appropriate. Plans are to be provided showing the location and manner of all fragmenta-tion and terrorist attack protection.

4.4.2 Where alternative tests or calculations have been carried out full details are to be submitted. They are to include details of the organisation involved, their experience, test or calculation procedures and the program or equations used.

4.5 Structural requirements

4.5.1 Where different threats, materials, multiple plate arrays are fitted alternative methods may be used to determine the fragmentation resistance, for example:

- Penetration equations.
- Finite element and fluid-codes.
- Experimental methods.

Ascending the levels of calculation complexity is not simply a matter of increased cost in design, the increase complexity potentially offers the reward of reduced protection requirement for the given threats.

4.5.2 Armour spaced normal to the threat can reduce the total thickness by up to 30 per cent. It may also be effective for bullets provided the gap between plates is greater than 1,0 m.

4.5.3 For Level I fragmentation protection, the equivalent thickness of steel is to be in accordance with Table 2.4.2.

4.5.4 For Level II fragmentation protection, the equivalent thickness of steel is to be determined from Fig. 2.4.2.

Table 2.4.2 Level I fragmentation protection

Material yield strength N/mm^2	Transverse bulkhead or deck thickness mm	Longitudinal bulkhead thickness mm
235	6,5	6,0
355	6,0	5,5
550	5,5	5,0
RHA	5,0	4,5

NOTE
RHA is defined as rolled homogenous armour.

4.5.5 For Level III fragmentation protection, the equivalent thickness of steel is to be determined from Fig. 2.4.3. Protection will normally be required to be provided by several bulkheads or specific armour and the graph can serve only as a guide. The structural protection for this type of threat will generally be specially considered based on the particular weapon characteristics and protection arrangements. It should also be noted that many modern missiles generate controlled fragments which will need special consideration.

4.5.6 The graphs are produced based on a 50 per cent probability of perforation for penetrators perpendicular to the target.

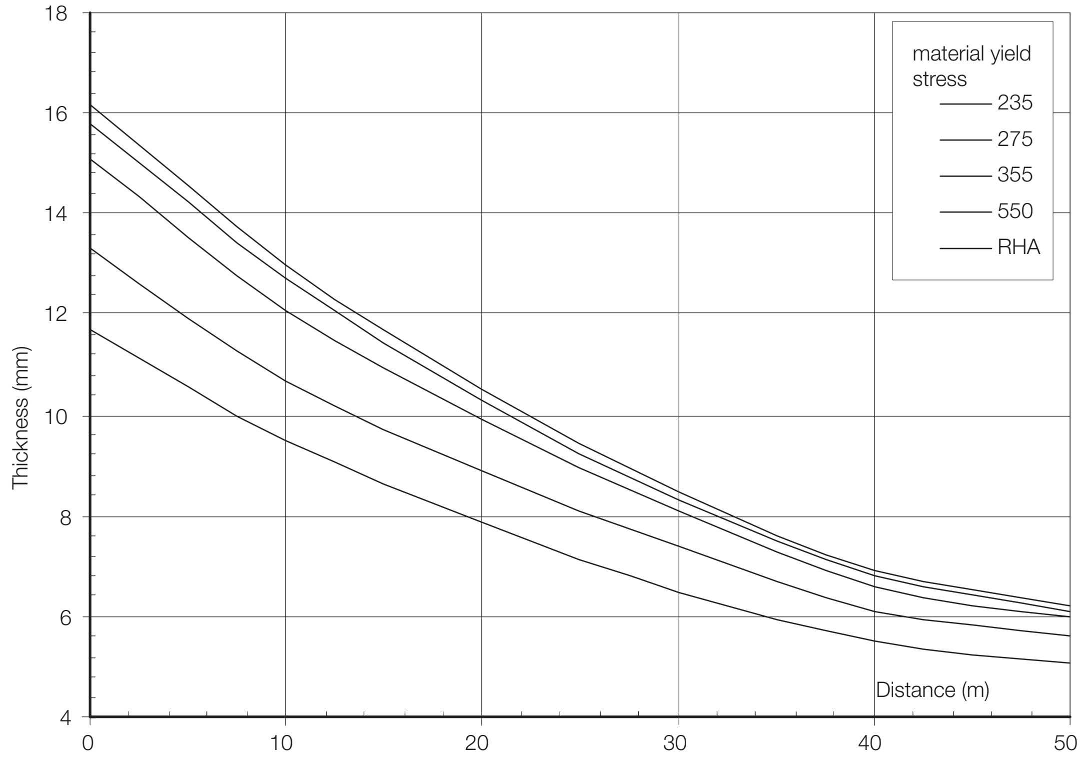


Fig. 2.4.2 Level II fragmentation protection

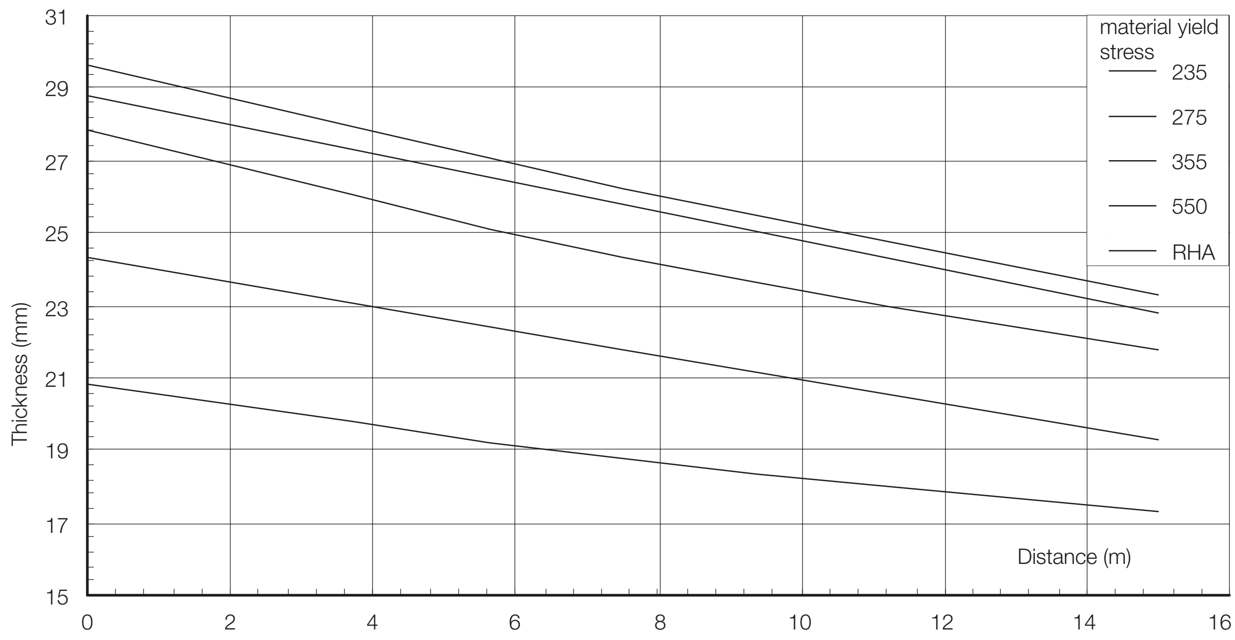


Fig. 2.4.3 Level III fragmentation protection

Section 5
Underwater explosion (shock)

5.1 General

5.1.1 There are two principal loading mechanisms associated with the underwater detonation of a conventional high explosive ordnance:
- shock wave loading;
- bubble flow loading.

5.1.2 The energy released is in general, equally divided between shock wave energy and the energy contained within the superheated high pressure bubble of gaseous explosion products.

5.1.3 The shock wave generated as the detonation wave passes into the water is a highly non-linear pressure pulse which propagates at a speed well in excess of the speed of sound in water (approximately 1500 m/s). However, within a few charge radii of the detonation point, it can be mathematically defined as an acoustic pressure pulse travelling at the speed of sound. Its amplitude falls off inversely with distance and its profile can be characterised by a pulse which has an infinite rise to a peak pressure followed by an exponential decay. The peak value and decay rate at a given field point are given by the similitude equations/coefficients for the explosive material.

5.1.4 In the meantime, the gas bubble begins to expand against the ambient hydrostatic pressure displacing water radially outward as incompressible flow. As it expands, it loses pressure and temperature but the inertia of the outwardly flowing water leads to an overshoot of the equilibrium state so that at maximum bubble radius, the gas pressure is well below the ambient. This initiates the collapse sequence, the gas bubble is recompressed, slowly at first but then rapidly, to a minimum volume by the hydrostatic forces. Because of the generation of a large pressure in the bubble during this stage the bubble begins to expand again and several other cycles may follow. The gas bubble and water interaction can be thought of as a gas spring - mass system. It has a periodicity associated with it but because of energy losses during the process, the spring constant and mass changes over each cycle leading to a change in the periodicity. At each minimum, that is, each recompression, additional pressure pulses are emitted which become weaker with each oscillation as shown in Fig. 2.5.1.

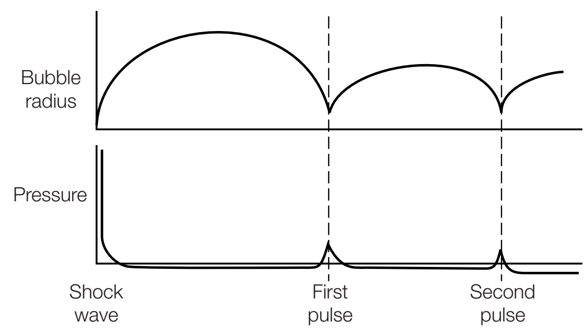


Fig. 2.5.1 Shock wave bubble pulse

5.1.5 The bubble is pulsating in a gravitational field and will have a tendency to migrate to the water/air boundary (the free surface). However, this bodily motion of the bubble centre may be influenced by the proximity of other boundaries such as the seabed or a nearby ship structure. The rate at which a bubble will migrate to the free surface is a function of the buoyancy forces generated when it is at its maxima and of the drag forces it experiences as it moves through the water. Because these drag forces are small when the bubble is at its minima, it tends to migrate vertically upwards more rapidly when at its smallest volume.

5.1.6 The fluid flow generated by the bubble dynamics is an important loading mechanism for a structure, within its sphere of influence. Normally bubble loading can be ignored if the bubble never approaches within a distance of around ten times the maximum bubble radius. The important feature of the bubble loading is its low frequency which is ideally suited to induce ship hull girder flexural motion. This flexural motion is commonly referred to as hull girder whipping. This loading mechanism is dealt with in Section 6. If the bubble is within one bubble radius of the ship structure, it is likely to form a jet which will impact on the structure. This bubble collapse mechanism will cause extensive local damage. It is generally not possible to efficiently design against this loading event for a **NS2** or **NS3** ship. For a **NS1** ship there may be sufficient residual strength to withstand such damage, but the extent of the damage will need to be determined by a specialist calculation and the capability of the hull using a residual strength assessment, *see* Section 7.

5.1.7 The shock wave loading is greatest at a point on the structure nearest to the detonation event and because of the fall-off with distance and the narrowness of the pulse width, it can be thought of as a local loading event. (In contrast, the bubble induced whipping of the hull girder is considered a global loading event.) The remainder of this section will focus on the shock loading event only.

5.1.8 There are no simple analytical or numerical techniques for reliably determining the shock resistance of a structure. A measure of the resistance to shock loading can be achieved by good design of the details of the structure to avoid stress concentrations which may lead to rupture. It is also possible to ensure that the plating thickness is matched to the assumed performance of the joints using a simple damage law. The inertial loads on the ship's structure caused by the equipment and its seatings can be determined by time domain analysis.

5.1.9 The shock performance of a ship's hull structure can be assessed solely by conducting shock tests (usually at scale). However, cost usually precludes this approach and a better strategy is to combine tests to determine failure criteria with numerical modelling using Finite Element methods. This complementary experiment/numerical simulation approach reduces the amount of testing required and also provides a method for extrapolating to full scale from scaled experiments.

5.1.10 Generally, for a normal ship structure, the explosion required to cause uncontrollable flooding or total loss of propulsive power is much less than that required to cause failure of a hull designed for normal sea loads. This is outside the scope of the shock notations which address structural aspects only.

5.1.11 Due to operational requirements, some vessel types, such as minesweepers, will be required to resist repeated shock loading at a specified level without degradation of the system or structural performance. Such vessels will also be expected to survive a single attack at a considerably higher shock loading level.

5.2 Threat level determination

5.2.1 The level of threat required is to be specified by the Owner. Three nominal levels of shock performance are presented in Table 2.5.1 together with an appropriate assessment methodology. These levels are denoted by the notations **SH1**, **SH2** or **SH3**, and are valid for a range of threat sizes. The notation that is appropriate for the level specified will be advised on request.

5.2.2 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

5.2.3 Threat levels and shock performance levels are clearly closely related. No matter how well designed and inherently robust a structure and its systems are, there will be a loading level which cannot be sustained. However, there are loading levels which can be sustained with varying degrees of structural and system degradation and these levels are a measure of the shock performance of the vessel. An important consideration is the balance that has to be achieved between system functionality and structural performance.

5.2.4 Two performance bounds can be considered for the shock response of structure:

- The first (lower) of these would be the loading level associated with the onset of material failure (assuming that careful design has ensured that no geometric instability will occur before this state is reached). This level is useful to know as it may have consequences for system functionality. For example, there may be problems associated with equipment mis-alignment because of permanent set of the supporting structure. This section of the Rules is concerned with establishing this lower bound.
- The second performance bound relates to structural integrity, this being the loading level at which there is no longer sufficient residual hull girder strength to resist normal environmental loading. This is addressed in a separate assessment which is defined by the residual strength notations **RSA1**, **RSA2** or **RSA3**, in Section 7. In conventional naval ships, this upper bound will be significantly higher but there will be little if any system functionality. The structure is considered acceptable when the hull girder is able to withstand reduced sea loads in accordance with Vol 1, Pt 5, Ch 4,5.

Table 2.5.1 Shock notation requirements

Notation	Basic requirements	Method	Hull structure acceptance criteria
SH1	Detail design	Section 5.4 or testing/modelling	—
	Local strength assessment	Simple empirically based assessment	Minor plate dishing within construction tolerance limits and deformation within system and equipment limits. No global strength assessment
			Some deformation of plating secondary and primary structure and deformation within system and equipment limits
	Global strength assessment	**RSA1**, **RSA2** or **RSA3** procedure, *see* Section 7	Hull girder sufficient for design bending moment with damage defined above
SH2	Detail design	Section 5.5 or testing/modelling	—
	Local strength assessment	Fluid-structure interaction (FS1) modelling using a Finite Element and Boundary Element approach	Minor plate dishing within construction tolerance limits and deformation within system and equipment limits. No global strength assessment
			Some deformation of plating secondary and primary structure and deformation within system and equipment limits
	Global strength assessment	**RSA2** or **RSA3** procedure, *see* Section 7	Hull girder sufficient for design bending moment with damage defined above
	Shock trial	Shock trial at lower threat level	No loss of watertight integrity or hull damage
SH3	Detail design	Section 5.6 or testing/modelling	—
	Local strength assessment	Fluid-structure interaction (FS1) modelling using a Finite Element and Volume Element approach (Hydrocode)	Minor plate dishing within construction tolerance limits and deformation within system and equipment limits. No global strength assessment
			Some deformation of plating secondary and primary structure and deformation within system and equipment limits
	Global strength assessment	**RSA2** or **RSA3** procedure, *see* Section 7	Hull girder sufficient for design bending moment with damage defined above
	Shock trial	Shock trial at lower threat level	No loss of watertight integrity or hull damage

5.3 Notation assessment levels and methodology

5.3.1 Three levels of notations are given in Table 2.5.1, they represent nominal threats of increasing magnitude. For each level, there are requirements to assess the capability of the structure both locally and globally.

5.3.2 Ships that comply with the requirements of this section will be eligible for the shock notation **SH1**, **SH2** or **SH3**.

5.3.3 For ship with sea area notations **SA3**, **SA4** and **SAR**, the scantling requirements assigning a shock notation will be specially considered.

5.3.4 For ships where the machinery is in class (**LMC** notation) the requirements of Vol 2, Pt 1, Ch 2,4.10 should also be complied with.

5.3.5 Local assessment is to be carried out using an analysis method appropriate to the threat level as defined in Table 2.5.1. The global assessment need only be performed if significant permanent deformation occurs that could compromise global strength, generally, deflections of plating, secondary or primary structure significantly in excess of normal constructional tolerances. The structure is considered acceptable when:

- Elastic deflections are less than the temporary limits of machinery and systems.
- Permanent deflections are less than the limits of machinery and systems.
- Deflections and strain are less than the limits of the structure or applicability of the analysis method.

5.3.6 The assessment method or analysis used should be validated against shock trial results and the evidence made available. As an alternative to analysis, full or large-scale shock trials of a section of the ship can be used to validate the proposed design. For novel design arrangements or ship types, a combination of trials and analysis may be necessary, the requirements of which will depend on the threat level and type of structure or ship design.

5.3.7 Global assessment is to be made using the residual strength procedures outlined in Section 7 with the extent of damage being defined from the results of the local strength assessment rather than the damage radii. For the **RSA1** procedure, the damaged structure is to be removed from the analysis. For the **RSA2** or **RSA3** procedure, if the damage is limited, the geometry of the damaged structure can be modelled and if the damage is severe, the structure is to be removed from the analysis. The structure is considered acceptable when the hull girder is able to withstand the design loads as specified in Part 5.

5.3.8 For the notation **SH1** a simple analysis may be performed which allows the motion response at any point in the ship to be determined. This can be derived from experimental results or the Taylor plate equations given below. Once the motion response is known, the damage potential can be determined by comparing the response to an acceptance standard nominated by the Naval Authority.

Maximum velocity

$$V_{max} = \frac{2P_m}{\rho\, c} z^u \text{ m/s}$$

Time to maximum velocity

$$t_{max} = \frac{m}{\rho\, c} \left(\frac{1}{1-z}\right) \log_e \left(\frac{1}{z}\right) \text{ seconds}$$

where

$$z = \frac{m}{\rho\, c\theta}$$

$$u = \frac{z}{1-z}$$

θ = decay constant of explosive charge in seconds
P_m = peak pressure in N/mm^2
ρ = density of water in kg/m^3
c = speed of sound in water in m/s
m = structural mass per unit area in kg/m^3.

5.3.9 For the notation **SH2**, a more complex assessment method is to be used which accurately models the physics of the rapid, dynamic, fluid structure interaction problem. In general, a finite element model combined with a suitable boundary element from proprietary software may be used.

5.3.10 For complex ships such as multi-hull designs a boundary element approach may not be suitable and a **SH3** analysis would have to be performed. Also, if non-linear fluid behaviour is important (i.e. hull cavitation or bulk cavitation) then a **SH3** analysis would have to be performed unless the finite element or boundary element code used had a suitable cavitation model.

5.3.11 For the notation **SH3**, a volume of fluid is to be modelled rather than a boundary element approach using a suitable hydrocode.

5.3.12 For **SH2** and **SH3** notations, the finite element analysis performed should be in accordance with the requirement of this section.

5.3.13 The calculations are to be carried out by a competent body with experience in non-linear analysis using a suitable code. Calculations are to be carried out in accordance with established procedures, a copy of which should be made available to LR together with a list of relevant experience when calculations are to be carried out for assignment of the shock notation.

5.3.14 The extent of the analysis model is to be from about $0{,}35L_R$ to $0{,}55L_R$ and encompass at least two major compartments and three watertight bulkheads. It is to be sufficiently large to avoid reflections within the structure from the boundaries, for the threats considered. For the assessment of structural strength, the structure need only be modelled to 1,0 m above the design water line. If the model is to be used to determine equipment response, all structure within that section should be modelled.

5.3.15 The model or versions of the model should encompass representative integral tank arrangements and hull penetrations, stabilisers, hull valves, the failure of which could lead to uncontrollable flooding. Penetrations, the failure of which will not lead to significant flooding or damage need not be considered. The tanks and penetrations need not actually be inside the section under consideration but should be sufficiently similar to represent structure outside the region modelled.

5.3.16 All masses above 100 kg should be included in the model together with an approximation of the mounting system if applicable.

5.3.17 The model should include at least one major machinery item or raft.

5.3.18 The response of hull panels depends upon a large number of variables which are both design and attack geometry dependent. To simplify the task, the following assumptions can be made:

- The charge detonates in the worst location, perpendicular to the structure under consideration.
- All welding is continuous and there are no manufacturing or material defects in the panels.

5.3.19 During the analysis, appropriate elements are to be used to couple the fluid medium and the structural model.

5.3.20 The shock wave can be represented by an exponentially decaying, infinite rise time pressure pulse which sweeps across the structure at the speed of sound.

5.3.21 Non-linear structural modelling can be accommodated in **SH2** and **SH3** analyses. In such cases, stiffeners should be modelled explicitly using shell elements of the appropriate thickness. Stiffener flanges should be modelled with at least two elements per half width or flange.

5.3.22 Initial imperfections in the hull plating are to be taken into account prior to the dynamic loading analysis.

5.3.23 In addition to analysis requirements, there are detail design requirements for each of the levels, which are based on historical work on shock. Alternatives to the requirements proposed will be considered on the basis of satisfactory analysis or shock trial results.

5.3.24 For the higher levels, **SH2** and **SH3** there is a requirement to carry out shock trials in accordance with established procedures, on the first ship in the class. The magnitude of the test is normally less than the design value for the hull and at a level that is appropriate for the equipment and systems.

5.4 Design guidance for level SH1

5.4.1 The structure should be designed to resist normal environmental loads. The inherent ruggedness of the structure should be sufficient to resist a low level threat.

5.4.2 To achieve an adequate shock performance against a threat of this level, the design emphasis should focus on maintaining a high level of system functionality. This can be achieved by using shock mounts, rather than trying to improve the basic shock resistance of structure.

5.5 Design guidance for level SH2

5.5.1 Tank boundaries are to be of equivalent scantlings to the hull boundaries.

5.5.2 Intermittent welding is not to be used on hull girder structure or tank boundaries below the water line or for 1 metre in way of the deck and shell connections.

5.5.3 Structural discontinuities are to be avoided and in general a minimum taper of 1:4 is to be applied to changes of structural section.

5.5.4 Bar keels are not to be fitted.

5.5.5 Tanks are to be integral with the ship's structure. For free standing tanks greater than100 litres, calculations demonstrating the capability of the tank and supporting structure are to be submitted.

5.5.6 For structure supporting seatings of equipment above 100 kg, calculations demonstrating the capability of the tank and supporting structure are to be submitted.

5.5.7 Main machinery mounts or raft mounts are to be supported on transverse web frames or floors forming part of the transverse ring structure. *See* Vol 1, Pt 3, Ch 2,3.2.2.

5.5.8 The size of longitudinal members passing through, or ending on, bulkheads are to be as small as possible, though still complying with the appropriate scantling requirements of Vol 1, Pt 6, Ch 3. Bulkhead stiffeners are to be fitted perpendicular to the shell plating.

5.5.9 Where deep longitudinal members are unavoidable, their connection to the bulkhead will be specially considered.

5.5.10 Bottom longitudinals are to be of a uniform size. Alternate large and small longitudinals are to be avoided as they may lead to high shear forces in the bulkhead.

5.5.11 Access holes in all primary framing members are to be avoided in areas of high shear stress. Where they are essential to the operation the ship they are to be circular and fitted with appropriate stiffening or compensation.

5.5.12 Frames on the bilge are to be provided with adequate lateral support, consideration should be given to the fitting of a shock stringer.

5.5.13 Lapped connections are not to be used to connect frames to floors.

5.5.14 All bulkhead stiffeners are to end on longitudinals, *see* Fig. 2.5.2.

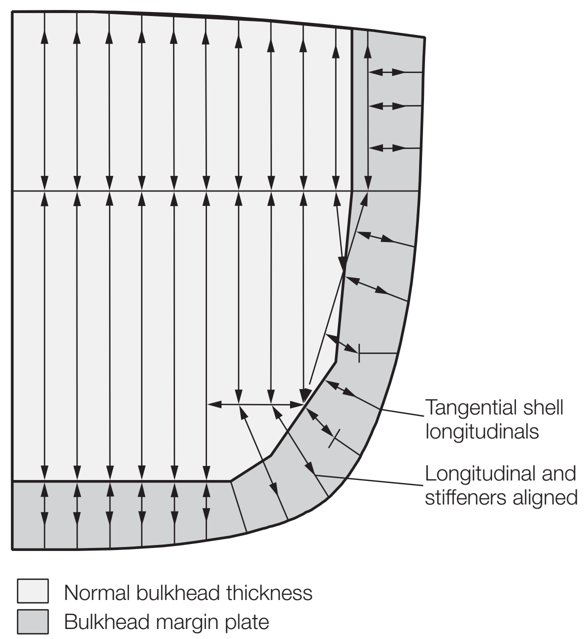


Fig. 2.5.2 Bulkhead stiffening

5.5.15 In transversely framed ships, bulkhead stiffeners are to be terminated on a shock stiffener welded to the bulkhead, parallel to, and spaced 500 mm from the shell. The bulkhead plating thickness is to be suitably increased in way. The shock stringer and bulkhead plate may be replaced by a web frame of suitable scantlings.

5.5.16 Bulkhead penetrations are to be grouped, away from the side shell and kept above the water line as far as is practicable.

5.5.17 Shell frames and deck beams are to be fitted in such a way as to minimise misalignment. Brackets where fitted are to be radiused and fitted with soft toes.

5.6 Design guidance for level SH3

5.6.1 Pillar bulkheads are to be used below the waterline in place of pillars.

5.6.2 It is recommended that symmetric stiffeners should be fitted to the to the underwater portion of the shell envelope.

5.6.3 Where a transverse framing system is used, the shock capability of the structure will be specially considered. Calculations supporting the use of particular design details are to be submitted.

5.6.4 All bulkhead stiffeners are to end on longitudinals, *see* Fig. 2.5.2. An increased thickness margin strake on bulkheads of thickness not less than 80 per cent of the adjacent shell plate thickness, the thickness of the adjacent shell stiffener or 6,5 mm. The margin plate is to have a width not less than 1,5 times the adjacent stiffener spacing or four times the depth of adjacent shell stiffeners.

5.6.5 Shell frames and deck beams fitted in such a way as to minimise misalignment. The frames are to be fitted within a tolerance of 0,3t_{fl} median line up to a maximum of 3,0 mm where t_{fl} is the greater thickness of the frames being connected. Where this is not possible, the frame is to be released over 20t_{fl} and realigned.

5.6.6 Where brackets are fitted, similar tolerances to 5.6.5 are to be applied subject to a suitable area being provided for weld fillet, *see* Fig. 2.5.3. Tripping brackets or intercostal stiffeners should be used to stabilise the frame at the bracket toes. Brackets are to be radiused and fitted with soft toes.

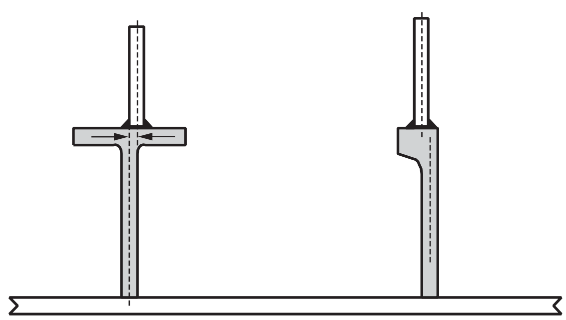


Fig. 2.5.3 Bracket connections

Section 6
Whipping

6.1 General

6.1.1 The effects of a non-contact underwater explosion are described in Section 5. Whilst the initial shock wave described in that section initiates whipping to some degree it is the pulsation of the bubble which leads to the majority of damage to the hull. The initial shock wave causes local hull damage and shock damage to the vessels equipment. In the strain history shown in Fig. 2.6.1 the initial shock wave can be seen to be not just the free response of an elastic system to an impulse as the amplitude continues to increase. There is a typical second kick to the system which stems from the first bubble pulse and which increases the response for several more cycles.

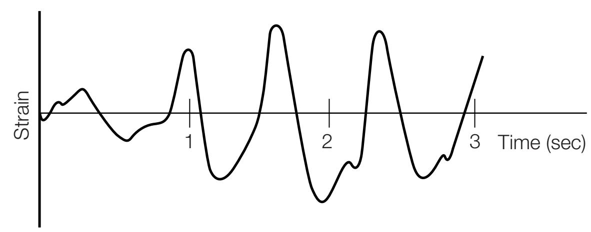


Fig. 2.6.1 Deck strains from hull whipping

6.1.2 The nature and behaviour of the gas bubble are dependent upon the warhead charge size, the explosive composition, the detonation depth and the influence of boundaries such as the sea bed.

6.1.3 The maximum radius of the bubble at the end of the first expansion phase is given by:

$$R_{bub} = 3,417 \left(\frac{W}{H + 10}\right)^{1/3} \text{ m}$$

where
W = bare charge equivalent weight of TNT, in kg
H = depth of the charge at the time of detonation, in metres.

6.1.4 The period of duration of the first bubble pulse is given by:

$$t_{bub} = 2,108 \frac{W^{1/3}}{(H + 10)^{5/6}} \text{ sec}$$

where
W and H are defined in 6.1.3.

6.1.5 Even a relatively modest warhead charge size can produce a bubble which displaces a large mass of water in a very short time frame. The momentum associated with this rapid incompressible flow of a sizeable volume of water constitutes a major loading mechanism for any structure within its sphere of influence.

6.1.6 The effect on the hull is a large amplitude vertical bending and vibration. This first introduces high shear forces at the quarter points which may cause shear wrinkling, this damage will probably not be catastrophic and the hull will go on to develop high compressive forces in the keel. These may cause buckling especially as the bottom structure may already be damaged from the initial shock wave. For extreme cases whipping may lead to the 'back breaking' and total loss of the ship.

6.1.7 An estimate of the hull natural frequency for steel ships is given by:

$$f_{s1} = \frac{215}{L_{OA}} \text{ Hz}$$

where
L_{OA} = the overall length of the ship, in metres.

6.1.8 The risk of a whipping response from a particular threat can be determined using the approximation for the natural frequency and the bubble characteristics of 6.1.4.

6.1.9 If the threat is closer to the hull than $2R_{bub}$ then the bubble loading is to be specially considered.

6.2 Threat level determination

6.2.1 The level to which a ship will be expected to survive an attack scenario that excites hull whipping is to be defined by the Owner and will remain confidential to LR.

6.2.2 The whipping threat level may be defined for a range of warheads detonating at a given stand-off distance and longitudinal (axial) location. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

6.2.3 It is also possible to undertake a parametric study to establish the detonation location which will lead to the worst case loading scenario. In this case, all possible hit locations that will induce whipping are assessed and the worst case induced bending moments are compared with a with an appropriate acceptance criteria. Contours from the keel of maximum threat size to induce failure can also be determined.

6.2.4 Where a shock threat is also being assessed for whipping effects, the warhead stand-off distance from the keel is set to be the same as that which induces the prescribed severity of shock. A series of axial locations are assessed to establish the worst case excitation which is compared to the appropriate acceptance criteria.

6.2.5 The non-dimensional measure of whipping severity, commonly referred to as Whipping Factor, is simply the ratio of maximum induced hull girder bending moment at a section to the critical bending moment for that section. Each threat location assessed will generate a whipping factor which can be assigned to that particular location. In this way a series of iso-Whipping Factor contours can be mapped in the fluid beneath the keel for a particular threat weapon. These contours define hit volume boundaries within which that particular weapon will induce a known level of whipping response.

6.3 Notation assessment levels and methodology

6.3.1 Ships for which a whipping assessment is performed will be eligible for a **WH1**, **WH2** or **WH3** notation as defined in 6.3.4 to 6.3.6.

6.3.2 There are two types of assessment to determine the whipping response of the hull girder:
- Simple 2-D beam model.
- Advanced 3D beam model.

6.3.3 For most ships a simple analysis will be sufficient to determine the whipping capability of the hull girder. An advanced analysis will be required when:
- more detailed information is required on areas of a ship which have been shown by simple analysis to be deficient under whipping loads, for example where there are large structural discontinuities variations;
- the ship design can not be idealised as a 2-D beam, for example when it has an unusual structural configuration or has low frequency modes of vibration in additional to its vertical flexural modes;
- there is a requirement to predict the extent of plastic deformation in a section;
- the whipping threats are assessed in a shallow water environment.

6.3.4 A **WH1** analysis method uses a 2-D beam representation and a failure level criterion based on the bending moment to induce material yield.

6.3.5 A **WH2** method of analysis uses a 2-D beam representation and a failure level criterion based on the section ultimate bending moments. This will require assessment using ultimate strength calculations at each of the discrete sections of the hull girder beam model.

6.3.6 A **WH3** method of analysis uses a 3-D definition of a section of the hull girder and geometric and material failure criteria implicit in the chosen finite element code.

6.3.7 In each case, it is to be demonstrated that the hull section remains below the defined failure limits for all threat scenarios.

6.3.8 For certain ship types such as minesweepers, it will be necessary to carry out several levels of analysis. An elastic analysis for threat levels which are expected to be survived on a regular basis. An elasto-plastic analysis at a higher threat level for which the ship is expected to survive.

6.4 Simple 2-D beam model

6.4.1 The modelling of ship interaction with explosion bubbles conveniently breaks down into a set of distinct sub-models.

6.4.2 The hull girder model is usually subdivided into at least twenty equal sections, each of which is assumed to form a 'Timoshenko' beam element. Since the stiffness and mass distributions may vary considerably along the length of a ship, a lumped mass/weightless beam representation is appropriate rather than a consistent mass model. The effect of shear deflection is to be included in the model.

6.4.3 The hull hydrodynamics may be modelled using standard strip theory to represent the effect of the inertia of surrounding water. At any lumped mass representing the hull girder, the added mass of water may be assumed using 'Lewis' forms coefficients. The added mass correction can be assumed to be constant for each mode of vibration.

6.4.4 For the bubble hydrodynamics it is assumed that the flow around the explosion bubble is inviscid and incompressible, that gaseous products obey ideal gas law, and that the bubble itself remains spherical. As a first approximation it may also be assumed that the bubble remains stationary but in general the migration is significant and should be considered. It is also assumed that the bubble motion is not modified by the presence of either the ship or the water surface. The loading model is to account for the dissipation of shock wave energy at the outset of detonation, generally achieved by using a modified initial radius for the bubble calculation.

6.4.5 The interaction hydrodynamics may also be assumed to be incompressible and inviscid consistent with the bubble hydrodynamics. The bubble radial flow may be resolved at the ship axis (the intersection line of the waterplane and the vertical centreline plane) at each lumped mass, into three components. Normally only the vertical z and athwartships y components need be considered as the bubble is assumed to be some distance from the ship. It may also be assumed that at each lumped mass, the transverse velocity around the whole section will be uniform in magnitude and direction.

6.4.6 The force acting on a strip is to account for this motion, plus the uniform pressure gradient assumed in the fluid which induces a buoyancy force proportional to the displaced volume of water. Wave generation and Bernoulli pressure effects may be neglected but the accelerations should account for the free surface reflection of the bubble.

6.4.7 Several assessment codes are available and calculation should be performed by a competent and experienced body with relevant experience and using recognised codes.

6.5 Advanced assessment

6.5.1 Advanced whipping assessments will normally be performed using a hybrid 3-D/2-D structural model for computational efficiency. However, care is to be exercised in the coupling of the 2-D beam elements to the 3-D section to ensure that this artificial boundary condition does not adversely influence the analysis. As an alternative, the ship may be defined as a full 3-D shell model. In which case, it may be possible to invoke symmetry to reduce the problem size and reduce the computational burden.

6.5.2 More than one option exists for modelling the fluid domain. It may be modelled using a boundary element approach and coupled to the structural domain using a Doubly Asymptotic Approximation. Alternatively, a computationally intensive volume fluid element approach employing an Eulerian code may be used. This fluid domain model would have to be coupled to the Lagrangian structural domain through a general or arbitrary coupling scheme. The detonation process and the bubble development would be physically modelled in this approach. A combined approach would entail modelling an island of fluid around the ship, truncated by a boundary element surface on which a bubble loading model would be applied.

6.5.3 For surface ship problems, whichever solution strategy is adopted, the fluid solver must be able to cope with the proximity of the bubble to the free surface and where appropriate reflections from the sea bed. Analysis is to be undertaken by a competent and experienced body using recognised techniques and with the relevant expertise necessary to establish the correct interface strategy between structural and fluid element meshes.

■ *Section 7* Residual strength

7.1 General

7.1.1 This Section details the determination of the threat levels and methodology to be adopted in the attainment of an **RSA1**, **RSA2** or **RSA3** notation.

7.2 Threat level determination

7.2.1 The level to which a ship will be expected to structurally survive an attack scenario that results in weapon damage is to be specified by the Owner and will remain confidential to LR.

7.2.2 The threat level may be defined for a range of warheads detonating at given internal positions or UNDEX stand-off distances with defined longitudinal locations. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

7.2.3 Generally, fragmentation scenarios are not included in residual strength assessments since the damage is usually localised. However, any significant structural damage resulting from fragmentation (as determined in Pt 4, Ch 2,4) must be considered. Similarly, any damage from an external blast threat weapon must also be included (Pt 4, Ch 2,2). In addition, residual strength calculations must be used in conjunction with level 2 whipping analysis (Pt 4, Ch 2,6).

7.3 Notation assessment levels and methodology

7.3.1 Ships for which a residual strength assessment is carried out will be eligible for a **RSA1**, **RSA2** or **RSA3** notation as defined in 7.3.6 to 7.3.8.

7.3.2 The assessment of the residual strength capability of a ship is to be performed as defined in Pt 6, Ch 4,4.

7.3.3 There are three methods of assessment that may be used to determine the damaged residual strength of the hull girder:

- Simple 2-D cross-section elastic model.
- 2-D ultimate strength model.
- Advanced 3D Finite Element Methods.

7.3.4 In the case of a mine warfare ship or NS3 ships, a 2-D elastic analysis will normally be sufficient. For most other naval ships, a 2-D ultimate strength analysis would normally be required to determine the damaged residual strength at a particular frame location along the hull girder.

7.3.5 An advanced 3D analysis incorporating initial deformations and residual stresses will be required when:

- More detailed information is required throughout one or more compartments along the length of the ship which have been shown by the more simplified 2-D ultimate strength analysis to be inadequate. This may be necessary, for example, where there are large structural discontinuities in hull girder strength.
- The ship design cannot be reduced to a 2-D beam or ultimate strength description, for example, when it has an unusual structural configuration.

7.3.6 A **RSA1** analysis method uses a 2-D elastic cross-section representation and a failure level criterion based on the calculated bending moment being greater than both the design hogging and sagging bending moments at the sections considered to be most critical.

7.3.7 A **RSA2** method of analysis uses a 2-D ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactory compared to the design bending moments in both hogging and sagging. This will require assessment using ultimate strength calculations at no less than three damaged positions along the length of the hull.

7.3.8 A **RSA3** method of analysis uses a 3-D definition of a section of the hull girder and relies on geometric and material failure criteria implicit in the chosen finite element code. It could also include coupled Euler-Lagrange formulations to specifically account for internal and external blast effects, UNDEX shock and whipping.

7.3.9 In each case, it is to be demonstrated that the hull girder remains below the defined design hogging and sagging design bending moment failure limits for all prescribed threat scenarios.

7.3.10 For certain ship types, such as mine-sweepers, it will be necessary to carry out several levels of analysis. An elastic analysis should be carried out for threat levels which are expected to be survived on a regular basis and geometric and material non-linear analysis at higher threat levels for which the ship is expected to survive.

7.4 Definition of damage

7.4.1 The damage radius is a measure of the extent of the damage caused by specific above water attack scenarios. This is shown diagrammatically in Fig. 2.7.1, where the assumption of a detonation mid-compartment is shown and the extent of damage is indicated by the extent of the damage radii. Assumptions about position and extent of damage radii are dependent on warhead characteristics. In general, the radii is to be vertically positioned such that it removes the maximum amount of material or has the greatest effect on the sectional inertia.

7.4.2 The damage radii can be determined from:

$$r = f_z W^{1/3} \quad \text{m}$$

where

f_z = scaled distance dependent on ship type
W = equivalent weight of TNT, in kg.

7.4.3 Once a damage radius has been determined, the simplest method of accommodating damage is to remove all structure within and touching the damage radii from the residual strength calculation.

7.4.4 For underwater shock (UNDEX), hull plating failure can be derived from angle hull shock factor, as defined in Fig. 2.7.2, exceeding appropriate hull lethality levels. The angled shock factor may be determined from:

$$SF = \frac{W^{0,5}}{R} f(\theta)$$

where

W = equivalent charge weight of TNT, in kg
R = distance from charge, in metres
$f(\theta)$ = threat angle function, *see* Fig. 2.7.2.

7.4.5 Special consideration will be given to the effects of damage to box type strengthening structure, armour plating, high yield strength materials, double skin hulls and blast strengthened bulkheads.

7.4.6 Generic damage can be generated using pseudo-random hit probability algorithms and repeated application of such algorithms can be used to represent successive weapon hits. Specific damage is difficult to quantify but can be estimated by using damage radii techniques for above water structure and by assuming critical shock factor levels for below water structure.

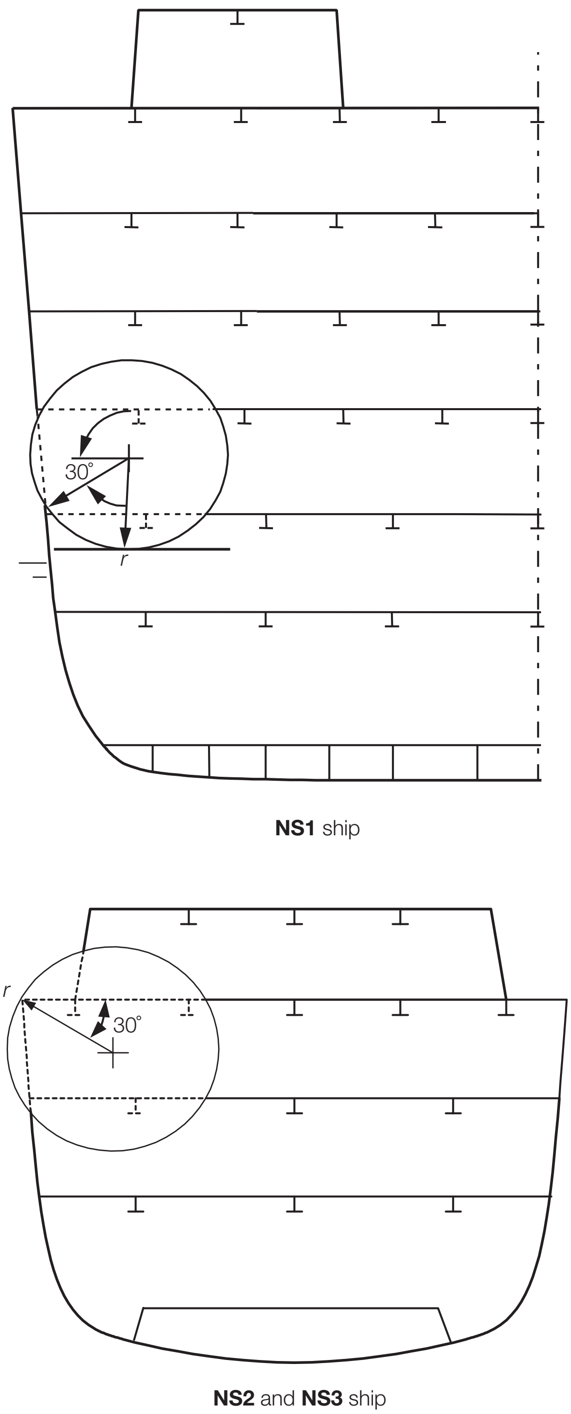


Fig. 2.7.1 Determination of damaged structure

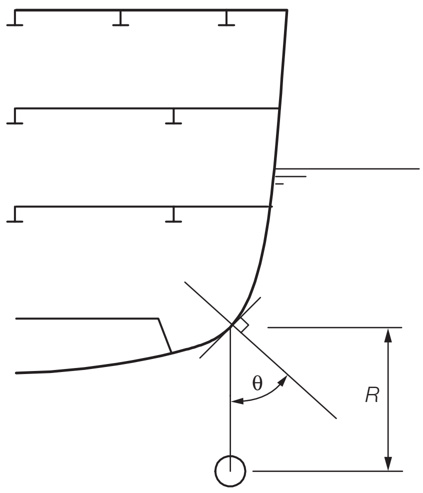


Fig. 2.7.2 Angle shock factor

■ *Section 8*
Strengthening requirements for beach landing operations

8.1 General

8.1.1 These requirements are in addition to those of Pt 6, Ch 3 for bottom shell structure. They need only be applied to those areas of the hull at risk from grounding during beach landing operations. These areas are to be agreed between the Owner, Builder and LR at an early stage in the plan approval process. A distinction is made between those areas likely to see impact loads on beaching and those where contact due to grounding will occur after the initial beaching.

8.1.2 The Rules assume that the ships will be brought into shallow water and up to the beach in a controlled manner and that procedures are in place and on board for the operation of these ships. The beach is assumed to be free of rocks of substantially greater projection than the depth of the rubbing strake.

8.1.3 Depending on the operational profile of the ship the minimum bow height given in Pt 3, Ch 2,5.3 will be specially considered.

8.1.4 Loading ramps are to be in accordance with the requirements of Ch 3,5.

8.1.5 Due regard is to be given to forces imposed on the ship and loading ramps by ship motions in shallow water both by impact from surf, the beach, and vehicles used to manoeuvre ships on the beach.

8.2 Minimum plate thickness

8.2.1 For areas subject to impact and grounding the thickness determined from Pt 6, Ch 3 is to be increased by 20 per cent and is in no case to be taken as less than 7 mm.

8.2.2 For operation in Arctic and Antarctic conditions the material grades are to be in accordance with the requirements of Pt 6, Ch 6,2 Material Class II.

8.3 Bottom stiffening

8.3.1 Secondary stiffening is to be designed in accordance with the requirements of Pt 6, Ch 3 with the modulus increased by 20 per cent. For impact areas the spacing of stiffeners is not to be greater than 500 mm.

8.3.2 Primary structure is to be designed in accordance with the requirements of Pt 6, Ch 3. An additional load case with the forces imposed from global bending and grounding forces uniformly distributed over the bottom in contact with the beach is to be considered. In the absence of specific information, not more than 50 per cent of the bottom structure is to be assumed to be in contact with the beach. The primary structure is also to be capable of supporting the concentrated loads imposed by loading or unloading vehicles.

8.3.3 Primary and secondary structure is to be continuously welded throughout areas subject to grounding.

8.3.4 Lugged connections or fully welded collars of the type shown in Fig. 2.8.1 are to be used. Alternative equivalent arrangements will be individually considered.

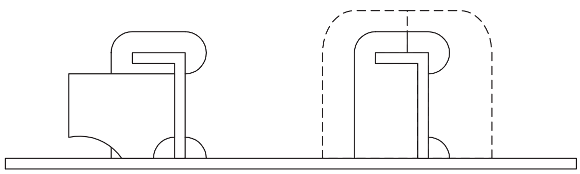


Fig. 2.8.1 Collar arrangement

8.3.5 Transverse floors are not to be spaced more than 1,25 m for transversely framed structure or 1,85 m for longitudinal framed structure.

8.3.6 One side girder each side of the centreline is to be fitted in addition to the requirements of Pt 3, Ch 2,3.5 or 3.6.

8.3.7 Transverse floors and girders are to be suitably stiffened with web stiffeners spaced not more than 1,25 m apart.

8.4 Global strength

8.4.1 For ships with L_R > 50 m grounding conditions in addition to the loading conditions of Pt 6, Ch 4 are to be assessed. The number and type of loading conditions will be determined by the operational requirements of the ship. In some cases residual strength calculations will be required.

8.4.2 If L_R > 50 m and areas of the bottom shell within 0,3 to 0,5L_R are at risk from grounding the thickness of the bottom shell and longitudinal structure will be specially considered.

8.5 Rubbing strakes

8.5.1 Rubbing strakes or barwhales are to be fitted to the bottom shell. In longitudinally framed ships they are to be placed directly below longitudinals. Typical arrangements of rubbing strakes are shown in Fig. 2.8.2. Usually they consist of a steel frame welded to the hull supports with a bolted connection to softer material but rubbing strips can be constructed of solid steel sections. They are to be free of projections or other discontinuities which could lead to damage of the shell plating.

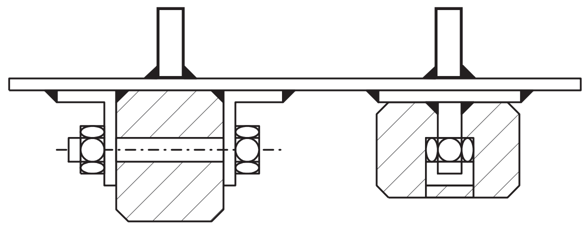


Fig. 2.8.2 Rubbing strakes

8.5.2 Rubbing strakes are to be spaced not less than 1,5 m apart. For closer spacing the thickness of the bottom shell will be specially considered.

8.5.3 The rubbing strake housing both internally and externally is to be efficiently coated to prevent corrosion. Where different materials are used the materials are to be selected or insulated to ensure that there is no galvanic corrosion.

8.5.4 Rubbing strakes are to be continuously welded to the hull. Butts between sections of rubbing strake are to be butt welded together before being welded to the hull. Where this is not possible, ceramic rather than copper backing strips are to be used.

8.5.5 Rubbing strakes are to be of the same grade of steel as the shell plate to which they are attached.

8.5.6 The ends of rubbing strakes are to be tapered at an angle of not less than 1 in 3 with no discontinuities in the welding in this region. Where not supported by internal longitudinals, the ends of strakes are to be arranged to pass 30 to 50 mm over the end of transverse frames or floors.

8.5.7 Due consideration is to be given to the depth of the rubbing strakes with regard to the nature of the beach. In no case are they to be less than 100 mm projection.

■ *Section 9* Military installation and operational loads

9.1 Weapon recoil, blast and efflux loads

9.1.1 Loads resulting from weapon launch may include recoil effects, blast and missile efflux pressures, and in general will be impulsive. These three types of load are estimated in different ways and will be covered in turn.

9.1.2 Gun and mortar recoil loads will generally be obtained from the manufacturer's documentation. If the natural frequency of the supporting structure is more than four times the firing rate and at least 50 per cent higher than the frequency derived from the time to maximum force, then a dynamic load factor of 1,6 may be used for a first estimate. If the gun is mounted immediately above an effective bulkhead then the structural resonant frequencies will be much higher and a dynamic load factor of 1,2 may be assumed. The stiffness of the supporting structure should be adequate for the loads imposed and in accordance with the manufacturer's recommendations.

9.1.3 The assessment of structure is to be made at the azimuth and elevation of the gun that produces the maximum demands on each component of the support structure. These will usually be ahead and abeam and at 0° and maximum elevation, although additional calculations should be made at the 45° positions vertically and horizontally against the resolved in-plane and normal elements of the load which occur simultaneously.

9.1.4 The load on the structure due to gun blast is in the form of a short-lived transient overpressure; values of this overpressure should be available in the manufacturer's documentation for the weapon as curves of pressure against distance from the gun muzzle. The pressure will act only for a time of the order of 10 ms so the structure, with a much higher natural response period, is unable to react to the full overpressure and it is sufficient to design to an equivalent static pressure using the dynamic load factors specified in Pt 6, Ch 2,6. Guns with a high rate of fire, typically greater than 30 rounds per minute, may induce a forced vibration and will be specially considered.

9.1.5 Should blast pressure curves not be available then a spherical approximation to the equivalent static design pressure P_g can be found from the following equation for ϕ_m values in the range 80 mm to 120 mm

$$P_g = 2\,(1 + \cos\theta)^2 \left(\frac{\phi_m}{x}\right)^{1,5} x\ 10^3 \quad \text{kN/m}^2$$

where

ϕ_m = the bore of the gun, in mm
x = the distance from the muzzle of a point at which the pressure is required, in mm
θ = the angle to the centre-line of the barrel

As shown in Fig. 2.9.1.

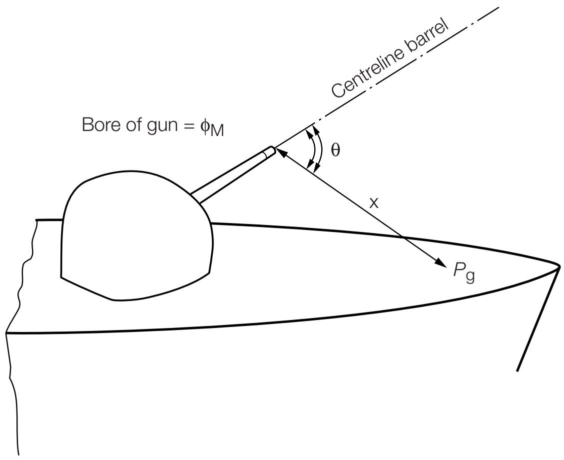


Fig. 2.9.1 Gun blast geometry

9.1.6 Missile efflux blast loading can be predicted by considering the rate of change of momentum of the efflux where it strikes the structure under consideration. However, when calculating the equivalent design load allowance must also be made for the dynamic response of the structure. For practical purposes therefore it is sufficient to design for the thrust averaged over a cone of semi-angle b and the resultant equivalent static pressure P_m may be found from

$$P_m = f_{DLF}\left(\frac{T_m}{A}\right)\left(\frac{\sin\alpha}{\sin\alpha + \tan\beta\cos\alpha}\right) \text{kN/m}^2$$

where

f_{DLF} = a dynamic load factor relating to variations in the efflux pressure and can be taken as 1,5
T_m = thrust, in kN
α = angle (25° < α < 90°) to the structure, in degrees
A = projected area of cone, in m^2
β = the efflux cone semi-angle in degrees and can be taken as 3°

As shown in Fig. 2.9.2.

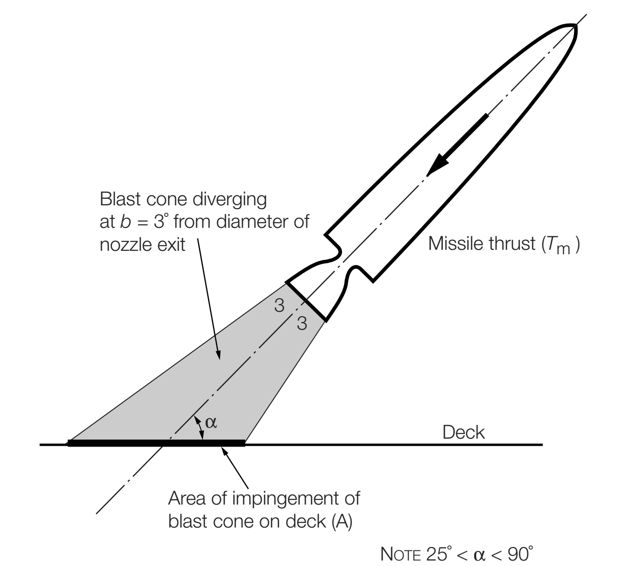


Fig. 2.9.2 Missile thrust geometry

9.1.7 Missile efflux will generally be at high temperature and may contain particulates. Protection is to be provided for ship structure and equipment upon which the efflux may impinge during launch.

9.2 Replenishment at sea loads

9.2.1 The loads imposed on the ship's structure will depend on the operation of the vessel during RAS operation and what weight of stores is to be transferred.

9.2.2 Guidance on representative arrangements is presented in Fig. 2.9.3. It is the responsibility of the Owner to define the design load values. The line of action of the forces is to be considered for all possible angles that might occur during replenishment operations.

9.2.3 In the absence of any specific information the RAS jackstay point is to be designed for 160 kN at 20° either side of the vertical and 20° either side of the horizontal. The outhaul securing point and hose pendent securing point are to be designed for 40 kN 20° either side of the vertical and 0° to 45° below the horizontal.

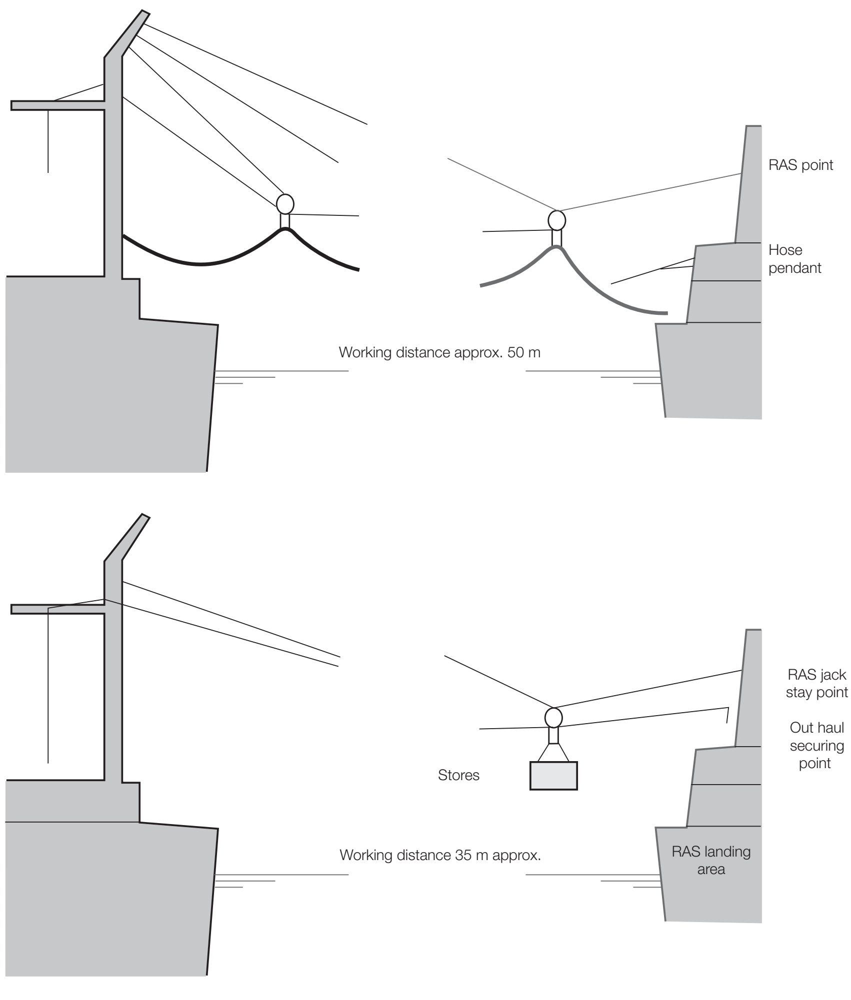


Fig. 2.9.3 Replenishment at sea loads

9.2.4 The structure is to be designed such that the stress from RAS operations in no part of the structure exceeds 70 per cent of the yield stress of the material under test conditions and 35 per cent of the yield stress of the material under normal working conditions.

9.2.5 For structure supporting RAS equipment, materials are to be in accordance with Table 6.2.1 in Vol 1, Pt 6, Ch 6.

9.2.6 Where tripods, gantries or masts are used for RAS operations the buckling strength of members in compression is to be specially considered.

9.2.7 A clear area is to be provided for RAS operations and the landing area for RAS operation is to be suitably strengthened for impact loading and concentrated equipment loads.

9.2.8 The design load used in the determination of scantlings for tanks used in RAS operation are to take due account of the maximum loads experienced in service. *See* Pt 5, Ch 3,5.

■ *Section 10*
Aircraft operations

10.1 General

10.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the ship structure. All ships operating aircraft are to comply with the requirements of this Section and will be assigned an **AIR** notation.

10.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. Consideration is to be given to air flow over the landing area and the impingement of hot exhaust gases on equipment in the flight path.

10.1.3 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

10.1.4 Equipment and vehicles using the landing area will also need to be assessed to identify the most onerous load in accordance with Pt 5, Ch 3.

10.1.5 Special consideration is to be given to the insulation standard if the space below the aircraft deck is a high fire-risk space.

10.1.6 These rules assume that the aircraft are fitted with oil/gas dampers and pneumatic types, different under carriage arrangements will be specially considered.

10.1.7 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

10.1.8 Suitable fire fighting equipment and services should be arranged on the landing deck, manoeuvring and parking areas as defined by the Naval Authority. Arrangements are to be made for drainage of the platform, including drainage of spilt fuel. Fire protection should also to be arranged between spaces containing aircraft and other areas of the ship. Special consideration should be given to aircraft handling arrangements and the possible passage of spilt fuel.

10.2 Definitions

10.2.1 OLEO load is defined as the load which will cause the damper and tyre combination to reach the end of their travel. OLEO loads should not generally be used to determine loads from the undercarriage on the flight deck. OLEO loads do not always reflect the loads that can be imposed by an aircraft landing on a ship. Loads should be derived using the vertical velocities specified in Table 2.10.3. The ratios of OLEO loads may be used to determine the dynamic distribution of load from the undercarriage.

10.2.2 The all up weight (AUW) is the maximum that will be encountered for the specific application under consideration it includes the maximum weight of aircraft, personnel, fuel and payload:

- For helicopters the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload at all times.
- For manoeuvring of fixed wing aircraft the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload.
- For take-off of fixed wing aircraft the fuel weight is to be the maximum less the fuel required to transit to the take off position.
- For landing of fixed wing aircraft the AUW is to be as above except that the fuel weight is to be the maximum less that consumed by the shortest possible flight.

10.3 Documentation

10.3.1 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of aircraft to be used are also to be indicated.

10.3.2 Details of arrangements for securing the aircraft to the deck are to be submitted for approval.

10.3.3 A landing guide should be provided as part of the ships' documentation. This is to contain all the relevant design information on the aircraft for the ship, identification of landing parking and manoeuvring areas, tie down arrangements, weights and a summary of the design calculations. It is also to provide guidance on the suitability of the landing areas for other aircraft. The information is to be presented in a graphical form similar to that shown in Fig. 2.10.1. Unrestricted landings are aircraft weights which can occur up to the design sea state. Restricted landing with weights

higher than the design can occur but in a reduced sea state and are to be indicated on the diagram. Prohibited landings are aircraft weights that may not take place in any sea state. Different diagrams will be required for twin and single rotor helicopters and for aircraft as appropriate.

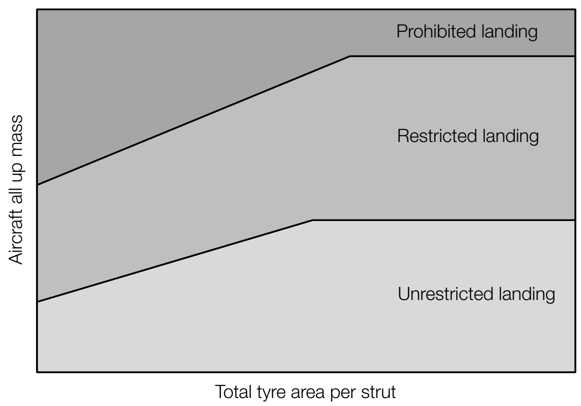


Fig. 2.10.1 Landing diagrams

10.4 Flight deck arrangements

10.4.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the aircraft, and is to be approached by a clear landing and take-off sector complying in extent with any applicable regulations.

10.4.2 Normally, for maximum flexibility in helicopter operations, the landing area is to be taken as a square not less than 1,25 times the rotor diameter. Where the operation of helicopters is restricted to known helicopter types, the areas of deck structure to be assessed for the landing condition are to be taken as squares not less than two times the maximum wheel strut spacing. The squares are to be centred on all the normal landing points, at all specified landing orientations, for all helicopters. For fixed wing aircraft the area to be considered will be determined by the operational requirements of the vessel. The landing area is to be clearly identified.

10.4.3 The takeoff and landing area are generally to be free of projections above the level of the deck. Projections above 25 mm may only be permitted where allowed by the aircraft undercarriage design standard. Projections outside the landing and takeoff areas are to be kept to a minimum such that they do not hinder aircraft manoeuvring operations.

10.4.4 The structure is to be designed to accommodate the largest aircraft type which it is intended to use. It is advised that an allowance be made for future growth of the helicopter weight such that future operations are not restricted to lower sea states.

10.4.5 Engine uptake arrangements are to be sited such that exhaust gases cannot as far as practicable be drawn directly into aircraft engine intakes during aircraft take-off or landing operations under anticipated operating conditions that include ship speed, ship motion and wind direction.

10.5 Loading

10.5.1 The load cases to be applied to all parts of the structure are defined in Table 2.10.6. in which:

f = 1,15 for landing decks over magazines or permanently manned spaces, e.g deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere

λ = reaction factor for the aircraft considered

W_{auw} = the maximum all up weight of the aircraft, in kN

W_{ty} = landing or static load, on the tyre print, in kN; with the centre of gravity in a position that causes the highest load. In the absence of specific aircraft manufacturers' information on the static or dynamic distribution of load, W_{ty} is to be taken as W_{auw} divided equally between the two main undercarriages ignoring the nose or tail wheel. For helicopters with twin main rotors W_{ty} is to be taken as W_{auw} distributed between all main undercarriages in accordance with the static load distribution.

10.5.2 The reaction factor λ may be determined from Table 2.10.1 where manufacturers' information is not available. Otherwise the information in 10.6 or 10.7 as appropriate may be used to estimate λ.

Table 2.10.1 Landing reaction factor

Aircraft type	λ
Helicopters	2,5
VSTOL aircraft	3,5
Fixed wing aircraft	5
NOTE Reaction factors are derived from the average values for marinised versions of aircraft.	

10.5.3 The reaction factor for helicopters using recovery systems will be specially considered.

10.6 Determination of λ for fixed wing aircraft

10.6.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

$$\lambda = \frac{V_L^2}{2g\,(\eta_T\,\delta_T + \eta_S\,\delta_S)}$$

where

λ = reaction factor

δ_S, δ_T = deflection of the shock absorber or tyre, in metres

V_L = vertical landing velocity including ship motions, in m/s

η_T = efficiency of the tyre typically assumed to be 0,47.

η_S = efficiency of the shock absorber, *see* Table 2.10.2.

Table 2.10.2 Shock absorber efficiency

	Steel spring	Rubber	Air	Liquid spring	OLEO
η	0,5	0,6	0,48	0,76	0,8

10.6.2 The vertical velocity is the maximum landing velocity derived from trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 6 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7 Determination of λ for helicopters

10.7.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

$$\lambda = \frac{V_L^2}{2g\,(\eta_T\,\delta_T + \eta_S\,\delta_S)} + \frac{(1 - f_L)\,(\delta_T + \delta_S)}{\eta_T\,\delta_T + \eta_S\,\delta_S}$$

where

λ, δ_S, δ_T, V_L, η_T, η_S are defined in 10.6.

f_L = the percentage of lift carried by the rotors at the time of landing typically 66 per cent.

10.7.2 The vertical velocity is the maximum landing velocity derived from ship trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 3,72 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7.3 For ships where helicopter operations are restricted to sea states lower than six the vertical velocities defined in Table 2.10.3 can be used.

Table 2.10.3 Vertical velocity

Sea state	Vertical velocity
6	3,72
5	3,35
4	2,97
3	2,60
2	2,23

10.7.4 Using a vertical velocity lower than the design given in this section, for example a land based helicopter, will result in higher probabilities of exceedance. The derivation of vertical velocity is such that it includes the effects of ship motions and pilot action and is independent of the design vertical velocity of the undercarriage.

10.7.5 Information on the probability of encountering a particular sea state for a sea area can be found in Pt 5, Ch 2,2.

10.7.6 For helicopters with skids, determination of the reaction factor will be specially considered.

10.8 Deck plating design

10.8.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\,s}{1000\sqrt{k_s}} - t_c \quad \text{mm}$$

where

α = thickness coefficient obtained from Ch 3,2 Fig. 3.2.1 using a value of β given by

β = tyre print coefficient used in Fig. 3.2.1 in Ch 3,2

$$\beta = \log_{10}\left(\frac{0{,}6F_{typ}\,\phi_1\,\phi_2\,\phi_3\,\gamma\,k_s^2}{9{,}81s^2}\ x\ 10^7\right)$$

k_s = higher tensile steel factor defined in Pt 6, Ch 5

s = stiffener spacing, in mm

F_{typ} = tyre force, in kN from Table 2.10.6

λ = reaction factor for the aircraft considered, *see* 10.5

γ = a location factor given in Table 2.10.4

ϕ_1, ϕ_2, ϕ_3 = are patch load correction factors determined from Table 2.10.5

t_c = permanent set correction in mm, *see* 10.8.2

a, s = the panel dimensions in mm, *see* Fig. 2.10.2

u, v = the patch dimensions in mm, *see* Fig. 2.10.2.

Table 2.10.4 Location factor, γ

Location	γ
On decks forming part of the hull girder (a) within $0{,}4L_R$ amidships (b) at the FP or AP	 1,18 1,0 Values for intermediate locations are to be determined by interpolation
Elsewhere	1,0

Table 2.10.5 Patch load corrections ϕ_1, ϕ_2, ϕ_3

Factor	Condition
$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\le s$ $u_1 = u$, but $\le a$
$\phi_2 = 1{,}0$ $= \dfrac{1}{1{,}3 - 0{,}3\,(a - u)/s}$ $= 0{,}77\,a/u$	for $u \le (a - s)$ for $a \ge u > (a - s)$ for $u > a$
$\phi_3 = 1{,}0$ $= 0{,}6\,(s/v) + 0{,}4$ $= 1{,}2\,(s/v)$	for $v < s$ for $1{,}5 > (v/s) > 1{,}0$ for $(v/s) \ge 1{,}5$

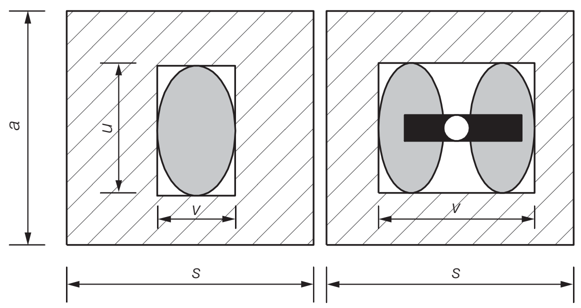


Fig. 2.10.2 Tyre patch dimensions

10.8.2 The permanent deflection correction, t_c, is a plating thickness reduction which can be applied if aircraft manoeuvring and take off, deck equipment operations allow some permanent set to occur

$$t_c = 0{,}001C\,s^n \text{ mm}$$

where

C = 0,00071 and n = 2,2 for moderate deformations
C = 0,0154 and n = 1,85 for large deformations

10.8.3 Moderate deformations are defined as those that will restrict manual manoeuvring of the aircraft. They will typically be 1,5 times the deflection expected from normal ship construction.

10.8.4 Large deformations are defined as those that will restrict operations to aircraft landing only with no wheeled vehicle operations they will typically be 2,5 times the deflections expected from normal ship construction.

10.8.5 If permanent deformation of the landing area plating is to be allowed then the plating must also be assessed for normal operations with t_c = 0,0 mm.

10.8.6 The permanent deflection correction is not to be applied to landing areas within $0{,}3L_R$ to $0{,}7L_R$ and other areas where there are significant in-plane stresses in the plate. Also the correction is not to be applied to areas where deflections could cause operational restrictions, for example the use of forklift trucks or rolling take off.

10.8.7 The static tyre print dimensions at W_{auw} specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 200 mm x 300 mm and this assumption is to be indicated on the submitted plan.

Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure

Condition	Loading					
	Plate F_{typ} kN	Stiffening			Support structure	
		P_{tyw} kN/m^2	Point loads F_{tys} kN	Self weight F_{tym} kN	vertical kN	horizontal kN
Emergency landing	$\lambda f W_{ty}$	0,2	$DLF\,\lambda f W_{ty}$	$(1 + a_z)\,W_s$	Self weight W_{pl} plus landing loads from all wheels	$0{,}5\,W_{auw}$
Normal landing	$0{,}6\,\lambda W_{ty}$	0,5	$0{,}6\,DLF\,\lambda W_{ty}$	$(1 + a_z)\,W_s$		$0{,}5\,W_{auw} + 0{,}5\,W_{pl}$
Take off (fixed wing)	$2{,}65\,W_{ty}$	0,5	$2{,}65\,W_{ty}$	$(1 + a_z)\,W_s$		
Manoeuvring internal	$1{,}6\,W_{ty}$	–	$1{,}6\,W_{ty}$	$(1 + a_z)\,W_s$		
Manoeuvring external	$1{,}75\,W_{ty}$	0,5	$1{,}75\,W_{ty}$	$(1 + a_z)\,W_s$		
Parking internal	$(1 + 0{,}6a_z)\,W_{ty}$	–	$(1 + 0{,}6a_z)\,W_{ty}$	$(1 + a_z)\,W_s$		
Parking external	$1{,}1(1 + 0{,}6a_z)\,W_{ty}$	2	$1{,}1(1 + 0{,}6a_z)\,W_{ty}$	$(1 + a_z)\,W_s$		

W_{ty} W_{auw} and f as defined in 10.5
λ is defined in 10.8
W_{pl} = structural weight of aircraft platform, in kN
W_s = structural weight of stiffener and supported structure, in kN is defined in 10.8
P_{tyw} = uniformly distributed vertical load over entire landing area, kN/m^2
DLF = Dynamic load factor — Fixed wing 1,35 for secondary stiffening, 1,5 for primary stiffening; Helicopters 1,2 for secondary stiffening, 1,5 for primary stiffening
a_z is defined in Pt 5, Ch 3,2

NOTES
1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.
2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.
3. Stiffening members may have more than one point load acting at one time.

10.8.8 Twin wheels are to be combined to form a single patch as shown in Fig. 2.10.2.

10.8.9 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying Ch 3,2, Fig. 3.2.1.

10.8.10 For decks fitted with sheathing greater than 25 mm a reduced plate thickness from that given in 10.8.1 may be specially considered.

10.8.11 For steel decks in frequent use and where no suitable protective sheathing or coating is used the thickness of the plating is to be increased by 1,5 mm to allow for wear and corrosion.

10.9 Deck stiffening design

10.9.1 The aircraft deck stiffening is to be designed for the load cases given in Table 2.10.6 with the aircraft being positioned so as to produce the most severe loading condition for each structural member under consideration. All possible positions and orientations are to be considered that can occur during aircraft operations.

10.9.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with the requirements of Table 3.2.3 in Pt 4, Ch 3, using the load cases defined in Table 2.10.6.

10.9.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures are used to determine the scantling requirements in association with the limiting permissible stress criteria given in Table 5.3.2 in Pt 6, Ch 5. The calculation is to be submitted for consideration.

10.9.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Pt 6, Ch 5.

10.10 Parking and manoeuvring areas

10.10.1 For areas designed for parking and manoeuvring of aircraft the maximum take off weight of the aircraft is to be used with the maximum fuel and payload.

10.10.2 For areas where only manoeuvring occurs and parking is restricted to designated and clearly marked areas then the scantlings of structure are to be calculated in accordance with 10.8 and 10.9 using the manoeuvring and parking loads given in Table 2.10.6 as appropriate. If parking areas are not clearly marked then the parking loads in Table 2.10.6 are to be applied to all areas of aircraft operation outside the landing area. W_{ty} may be determined from the static distribution of the load or in the absence of specific information shared equally between the tyres. The loads for non-pneumatic tyres will be specially considered.

10.10.3 Parking areas may not be taken less than two frame spaces or the tyre width plus 500 mm which ever is the greater. Consideration should be given to the use of removable lagging around these areas and at the adjacent beam bulkhead connection.

10.10.4 Additional forces from tie down arrangements on the structure need only be considered if the tensioning force applied exceeds that imposed by the forces from ship motions as defined in 10.14.

10.10.5 Decks subjected to a combination of parking and significant in-plane stresses will be specially considered.

10.11 Assisted take off

10.11.1 Where the aircraft jet is not parallel to the deck at the moment of launch or jet blast deflectors are used the structure is to be capable of withstanding the thermal loads imposed on the deck.

10.11.2 The structure of ramps used to assist take off are to be specially considered.

10.11.3 Structure surrounding catapults are to be effectively supported and designed for the maximum forces imposed by the launch system using the stress criteria given in Table 5.3.2 in Pt 6, Ch 5.

10.12 Arrested landing

10.12.1 Structure surrounding arresting gear is to be effectively supported and designed for the maximum forces imposed by the arrested aircraft using the stress criteria given in Table 5.3.2 in Pt 6, Ch 5.

10.13 Vertical recovery

10.13.1 The structure in way of the landing area and approach path is to be capable of withstanding the thermal loads imposed by hot exhaust gases.

10.14 Tie down forces

10.14.1 The force to be used in assessing the tie down points is to be determined from the calculations for the securing arrangements, in accordance with LR's LAME Code.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull ships of steel construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor, *see* Pt 6, Ch 5,3.1.1.

■ *Section 2* Vehicle decks

2.1 General

2.1.1 These requirements are applicable to longitudinally or transversely framed ships intended for the carriage of tracked vehicles, wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

2.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

2.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the ship's documentation and contained in a notice displayed on each deck. For wheeled vehicles, the wheel loading is to be taken as not less than 3,0 kN.

2.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, guidance for wear and tear allowances is given in 2.3. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and embarked personnel routes.

2.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

2.1.6 If wheeled vehicles are to be used on insulated decks or tanks tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

2.1.7 Suitable fire fighting equipment and services should be provided in the vehicle space. Arrangements should be made for ventilation and drainage of spilt fuel.

2.2 Definitions

2.2.1 **Load Area**. The load area is defined as the foot-print area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

2.3 Deck plating

2.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000\sqrt{k_s}} \quad \text{mm}$$

where

α = thickness coefficient obtained from Fig. 3.2.1 using a value of β given by

β = tyre print coefficient used in Fig. 3.2.1

$= \log_{10}\left(\dfrac{F_{typ}\, k_s^{\,2}}{9{,}81 s^2} \times 10^7\right)$

s = secondary stiffener spacing, in mm

F_{typ} = corrected patch load for plating, in kN obtained from Table 3.2.1, *see also* Fig. 3.2.1 and Table 3.2.2

s and k_s are as defined in 1.2.

2.3.2 Where transversely framed decks contribute to the hull girder strength or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, t_p, derived from 2.3.1 is to be increased by 1,0 mm.

2.3.3 In the absence of a specific requirement the thickness t_p derived from 2.3.1 is to be increased by a wear and wastage allowance of 1,5 mm for strength decks, weather decks, tank tops and inner bottom or 0,75 mm elsewhere.

Table 3.2.1 Deck plate thickness calculation

Symbols	Expression
a, s, u, and v as defined in Fig. 3.2.1 n = tyre correction factor as detailed in Table 3.2.2 F_{typ} = corrected patch load for plating, in kN λ = dynamic magnification factor W_{ty} = load, in kN, on the tyre print. For closely spaced wheels the area shown in Fig. 2.10.2 may be taken as the combined print ϕ_1 = patch aspect ratio correction factor ϕ_2 = panel aspect ratio correction factor ϕ_3 = wide patch load factor	$F_{typ} = \phi_1 \phi_2 \phi_3 \lambda W_{ty}$
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $\quad v_1 = v$, but $\leq s$ $\quad u_1 = v$, but $\leq a$
	$\phi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \geq u > (a - s)$ $= 0{,}77 \dfrac{a}{u}$ for $u > a$
	$\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\,(s/v) + 0{,}4$ for $1{,}5 > (v/s) > 1{,}0$ $= 1{,}2\,(s/v)$ for $(v/s) \geq 1{,}5$
	λ = 1,25 for harbour conditions = $(1 + 0{,}7n)$ for sea going conditions

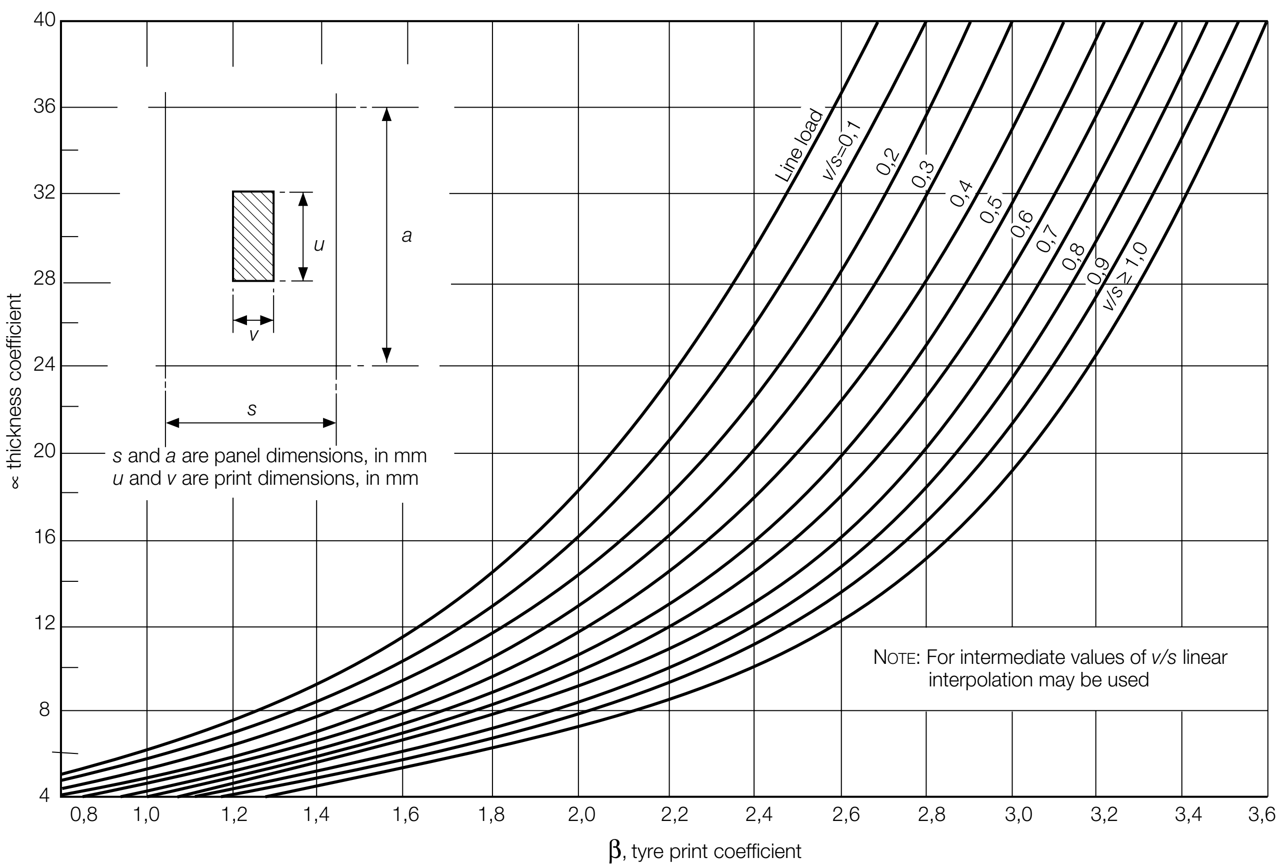


Fig. 3.2.1 Tyre print chart

Table 3.2.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

2.4 Secondary stiffening

2.4.1 The scantlings of vehicle deck stiffeners are to satisfy the most severe arrangement of print wheel loads.

2.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 3.2.3 using the loads defined in Table 3.2.4.

2.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

Table 3.2.4 Design load cases for primary and secondary stiffening and supporting structure

Condition	Loading		
	Stiffening		
	UDL P_{tyw} kN/m^2	Point loads F_{tys} kN	Self weight F_{tym} kN
Manoeuvring internal	—	$1,6W_{ty}$	$(1 + a_z)\, W_s$
Manoeuvring external	0,5	$1,75W_{ty}$	$(1 + a_z)\, W_s$
Parking internal	—	$(1 + n\, a_z)\, W_{ty}$	$(1 + a_z)\, W_s$
Parking external	2	$1,1\,(1 + n\, a_z)\, W_{ty}$	$(1 + a_z)\, W_s$

Symbols

W_{ty} = maximum effective load per wheel or group of wheels
W_s = structural weight of stiffener and supported structure, in kN
UDL = uniformly distributed load over entire vehicle area, kN/m^2
n = tyre correction factor in Table 3,2,4
a_z is defined in Pt 5, Ch 3,2

NOTES
1. For the design of the supporting structure for vehicle decks, the applicable self weight and horizontal loads are to be added to the parking area loads.
2. The vehicles are to be positioned so as to produce the most severe loading condition for each structural member under consideration.
3. Stiffening members may have more than one point load acting at any time.

Table 3.2.3 Secondary stiffener requirements

Scantling requirement	Load case	
	$d \leq l$	$d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{k_w F_{tys}(3l^2 - d^2)}{24l} + \frac{P_{tyw}\, s\, l^2}{10} + \frac{F_{tym}\, l}{10}\right)\frac{10^3}{f_\sigma \sigma_o}$	$Z = \left(\frac{k_w F_{tys}\, l^2}{10d} + \frac{P_{tyw}\, s\, l^2}{10} + \frac{F_{tym}\, l}{10}\right)\frac{10^3}{f_\sigma \sigma_o}$
Inertia (I) (cm^4)	$I = \left(\frac{k_w F_{tys}(2l^3 - 2d^2\, l + d^3)}{384l} + \frac{P_{tyw}\, s\, l^3}{288} + \frac{F_{tym}\, l^2}{288}\right)\frac{10^5}{f_\delta E}$	$I = \left(\frac{k_w F_{tys}\, l^3}{384d} + \frac{P_{tyw}\, s\, l^3}{288} + \frac{F_{tym}\, l^2}{288}\right)\frac{10^5}{f_\delta E}$
Web area (A_w) (cm^2)	$A_w = \left(\frac{k_w F_{tys}(m^3 - 2m^2 + 2)}{2} + \frac{P_{tyw}\, s\, l}{2} + \frac{F_{tym}}{2}\right)\frac{10}{f_\tau \tau_o}$ where $m = d/l$	$A_w = \left(\frac{k_w F_{tys}\, l}{2d} + \frac{P_{tyw}\, s\, l}{2} + \frac{F_{tym}}{2}\right)\frac{10}{f_\tau \tau_o}$

Symbols

l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Youngs Modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \leq s$
= s/w for $w > s$

F_{tys} = point load given in Table 3.2.4, in kN
F_{tym} = self weight load given in Table 3.2.4, in kN
P_{tyw} = weather deck load given in Table 3.2.4, in kN/m^2
f_σ, f_δ, f_τ are the structural design factors given in Pt 6, Ch 5
σ_o = specified minimum yield strength of the material, in N/mm^2
τ_o = shear strength of the material, in N/mm^2
$= \frac{\sigma_o}{\sqrt{3}}$

2.5 Primary stiffening

2.5.1 Generally the scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the loads defined in Table 3.2.4 and the limiting permissible stresses and deflection criteria contained in Pt 6, Ch 5.

2.6 Securing arrangements

2.6.1 The strength and stiffness of the holding down arrangements and supporting structure are to be in accordance with Ch 1,5.2.

2.6.2 Deck fittings in way of vehicle lanes are to be recessed.

2.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

2.7 Access

2.7.1 Bow doors are to comply with the requirements of Section 4.

2.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

2.7.3 Doors providing access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the fire requirements as defined by the Naval Authority.

2.8 Hatch covers

2.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

2.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck hatch cover, as applicable.

2.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations. The designers calculations are to be submitted.

2.9 Heavy and special loads

2.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

2.9.2 Due account is to be taken of the acceleration levels due to ship motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

2.10 Tracked and steel wheeled vehicles

2.10.1 Where it is proposed to carry tracked vehicles the patch dimensions may be taken as the track print dimensions and F_w is to be taken as half the total weight of the vehicle. Deck fittings in way of vehicle lanes are to be recessed.

2.10.2 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be used when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

2.10.3 A wear and tear allowance is to be added to the plating thickness and it is not to be less than that defined in 2.3.3.

2.11 Openings in main vehicle deck

2.11.1 Items such as portable plates in main vehicle deck for the removal of machinery parts, etc., may be arranged flush with the deck, provided they are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

2.11.2 Scuppers from vehicle or cargo spaces fitted with an approved fixed pressure water spray fire-extinguishing system are to be led inboard to tanks. Alternatively they may be led overboard providing they comply with Pt 3, Ch 4,7.1.3(a) and (b).

2.11.3 Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (not engine room or hold bilges) and the capacity of the tanks should be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided.

2.11.4 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

2.11.5 In addition, the requirements of 3.9.8 to 3.9.10 are to be complied with.

2.12 Direct calculations

2.12.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 3* Bow doors

3.1 Application

3.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

3.1.2 Other types of bow door will be specially considered.

3.1.3 Where the operational requirements dictate that the doors and ramps be deployed at sea or in the surf zone, the strength and operation will be specially considered.

3.2 General

3.2.1 The attention of Owners and Builder's is drawn to the additional statutory regulations for bow doors that may be required by the Naval Authority.

3.2.2 Bow doors are to be located above the vertical limit of watertight integrity. A watertight recess is normally permitted below the vertical limit of watertight integrity located forward of the collision bulkhead and above the deepest waterline, for the arrangement of ramps or other related mechanical devices. For any ship where bow doors may be open at sea or located below the vertical limit of watertight integrity, the enclosed spaces protected by the door or ramp are to be considered open as well as closed in damage stability or flooding conditions.

3.2.3 An inner door is to be fitted which is to be gasketed and weathertight. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the vertical limit of watertight integrity may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

3.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the vehicle space and arranged with fixed sealing supports on the aft side of the doors.

3.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 3.2.3.

3.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

3.2.7 The scantlings and arrangements of side shell and stern doors are to be in accordance with the requirements of Pt 6, Ch 3.

3.3 Symbols and definitions

3.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 3.3.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 3.3.2

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 3.3.2

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected are of the visor door, as shown in Fig. 3.3.2

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 3.3.2

d_{bv} = vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, *see* Fig. 3.3.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 3.3.1

k_s = higher tensile steel factor defined in Pt 6, Ch 5,3.1.1

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in Fig. 3.3.1

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 3.3.2

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 3.3.2

τ = shear stress, in N/mm^2

σ = bending stress, in N/mm^2

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2

= $\sqrt{\sigma^2 + 3\tau^2}$

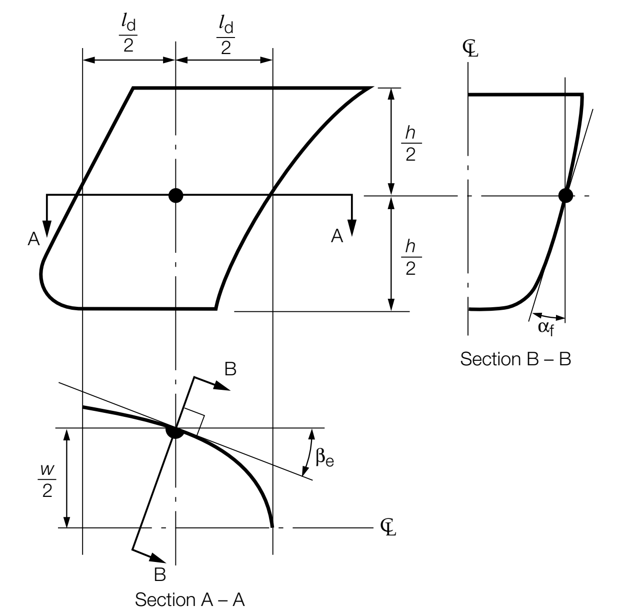


Fig. 3.3.1 Definition of α_f and β_e

3.3.2 **Locking device**. A device that locks a securing device in the closed position.

3.3.3 **Securing device**. A device used to keep the door closed by preventing it from rotating about its hinges.

3.3.4 **Side-opening doors**. Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

3.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

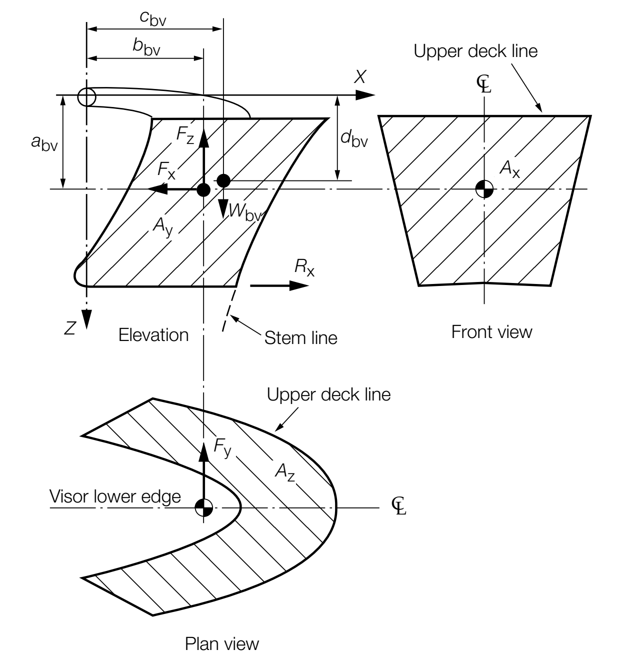


Fig. 3.3.2 Bow visor upward hinging

3.3.6 **Visor doors**. Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

3.4 Strength criteria

3.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 3.5. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

3.4.2 The bucking strength of primary members is to be verified as being adequate, *see* Pt 6, Ch 2,4.

3.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according the manufacturer's specification.

3.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k$ N/mm^2.

3.5 Design loads

3.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2{,}75\ \lambda_G\ C_H\ (0{,}22 + 0{,}15 \tan \alpha_f) \times \left(0{,}4V_{max} \sin \beta_e + 0{,}6L_R^{0,5}\right)^2 \quad \text{kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in Pt 1, Ch 2,2.2.4.

L_R = Rule length of ship, in metres, as defined in Pt 3, Ch 1,5.2.2

λ_G = service area factor for mono-hull ships, *see* Pt 1, Ch 2,3.5
= 1,0 for sea-going ships
= 0,8 for ships operated in coastal waters
= 0,5 for ships operated in sheltered waters

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 3.3.1

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 3.3.1.

3.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively. Where P_e is the external pressure, defined in 3.5.1, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 3.3.1. A_x, A_y, A_z and h as defined in 3.3.1.

3.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

3.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x\, a_{bv} + 10W_{bv}\, c_{bv} - F_z\, b_{bv} \quad \text{kNm}$$

where
W_{bv}, a_{bv}, b_{bv} and c_{bv} as defined in 3.3.1, F_x and F_z as defined in 3.5.2.

3.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

3.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h^2$, where h^2 is the distance, in m, from the load point to the top of the space enclosed by the visor, L_R as defined in Pt 3, Ch 1,5.2.2.

3.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

3.5.8 On ships with rounded nose bow and a large stem angle with the waterline, strengthening against horizontal impact loads is to be considered. Similarly, in ships with a flare angle of less than 60° with the waterline, strengthening against vertical impact loads to be considered.

3.6 Scantlings of bow doors

3.6.1 The strength of bow doors is to be equivalent to the surrounding structure.

3.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

3.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

3.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners.

3.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23{,}5Q_{bd}}{\sigma_o} \quad \text{cm}^2$$

where A_s, Q_{bd} and σ_o as defined in 3.3.1.

3.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

3.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 3.5.1 and permissible stresses given in 3.4.1.

3.6.9 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

3.7 Scantling of inner doors

3.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with an external pressure and permissible stresses given in 3.4.1. In general, formulae for simple beam theory may be applied.

3.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

3.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

3.8 Securing and supporting of bow doors

3.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

3.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 3.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 3.8.9 and 3.8.10 and the available space for adequate support in the hull structure.

3.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 3.5.4 to be not less than:

$$M_y = 10W_{bv}\,c_{bv} + 0{,}1(a_{bv}^2 + b_{bv}^2)^{0,5}\ (F_x^2 + F_z^2)^{0,5}$$

where W_{bv}, a_{bv}, b_{bv} and c_{bv} as defined in 3.3.1, F_x and F_z as defined in 3.5.2.

3.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 3.4.1.

3.8.5 For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x, and F_z.
Case 2 $0{,}7F_y$ acting on each side separately together with
$0{,}7F_x$ and $0{,}7F_z$.

where F_x, F_y and F_z are to be determined as indicated in 3.5.2 and applied at the centroid of projected areas.

3.8.6 For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x, F_y and F_z acting on both doors.
Case 2 $0{,}7\,F_x$ and $0{,}7F_z$ acting on both doors and $0{,}7F_y$ acting on each door separately.

where F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

3.8.7 The support forces as determined according to 3.8.5 and 3.8.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area, A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

3.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

3.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 3.4.1.

3.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 3.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\,d_{bv} + 5A_x\,a_{bv}\ \text{kNm}$$

where
W_{bv}, A_x, d_{bv} and a_{bv} as defined in 3.3.1.

3.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z – $10W_{bv}$), in kN, within the permissible stresses given in 3.4.1.

3.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be the same strength.

3.8.13 For side-opening doors, thrust bearings have to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 3.3.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose are to be submitted for appraisal.

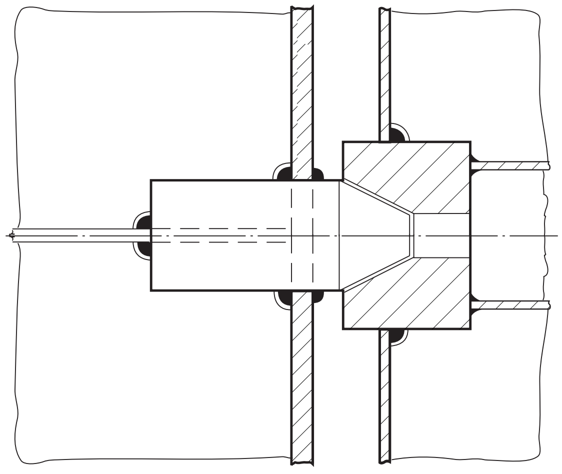


Fig. 3.3.3 Typical thrust bearing

3.8.14 The spacing for side and top cleats should not exceed 2,5 m and there should be cleats positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

3.9 Securing and locking arrangements

3.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

3.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the vertical limit of watertight integrity, of:
(a) the closing and opening of the doors, and
(b) associated securing and locking devices for every door.
Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

3.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

3.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

3.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

3.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function ‘harbour/sea voyage’, so arranged that audible alarm is given if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

3.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

3.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the machinery control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

3.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the vehicle deck level. If not discharged by a bilge suction, scuppers are to be provided port and starboard having a diameter of not less than 50 mm. Valves are to be fitted.

3.9.10 If the main vehicle deck is not totally enclosed, scuppers or freeing ports are to be provided consistent with the requirements of Pt 3, Ch 4,8.

3.9.11 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

3.10 Operating and Maintenance Manual

3.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:
(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.
This manual is to be submitted for approval and is to contain a note recommending that recorded inspections of the door supporting and securing devices carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

3.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 4*
Side, stern doors and other shell openings

4.1 Symbols

4.1.1 The symbols used in this Section are defined as follows:

d = distance between closing devices, in metres
k_s = material factor, *see* Pt 6, Ch 5,3.1.1 but is not to be taken less than 0,72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure
I = moment of inertia, in cm^4, of the stiffener or girder, in association with an effective width of attached plating determined in accordance with Pt 6, Ch 2,3.
σ = bending stress, in N/mm^2
σ_e = equivalent stress, in N/mm^2
= $\sqrt{(\sigma^2 + 3\tau^2)}$
σ_o = minimum yield stress of the bearing material, in N/mm^2
τ = shear stress, in N/mm^2.

4.2 General

4.2.1 These requirements cover service doors in the ship side (abaft the collision bulkhead) and stern area, below the weather deck and in enclosed superstructures.

4.2.2 For the requirements of bow doors, *see* Section 3.

4.2.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure, *see also* Pt 3, Ch 1,5.

4.2.4 In general, the lower edge of door openings is not to be below a line drawn parallel to the design draught.

4.2.5 When the lower edge is below the design draught or doors below the vertical limit of watertight integrity are to be opened at sea, the arrangements will be specially considered. In general, the enclosed spaces protected by the door are to be considered open as well as closed in damage stability or flooding conditions.

4.2.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two lower decks above the waterline.

4.2.7 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined in 3.3.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below, *see* Pt 3, Ch 1,5.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.3.4.

4.3.6 Where higher tensile steel is proposed, the plating thickness required in 4.3.4 and 4.3.5 may be reduced by $\sqrt{k_s}$.

4.3.7 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners.

4.3.8 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.9 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied. The design load is the uniformly distributed external sea pressure, p_e, as defined in 4.8.1. For minimum scantlings, p_e is to be taken as 25 kN/m^2 and the permissible stresses are as follows:

$$\tau = \frac{80}{k_s} \text{ N/mm}^2$$

$$\sigma = \frac{120}{k_s} \text{ N/mm}^2$$

$$\sigma_\varepsilon = \frac{150}{k_s} \text{ N/mm}^2$$

4.3.10 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.11 The stiffness of the edges of the doors and the hull structure in way are to be sufficient to ensure weathertight integrity. Edge stiffeners/girders are to be adequately stiffened against rotation and are to have a moment of inertia not less than:

$$I = 0{,}8 P_L\, d^4 \text{ cm}^4$$

where

P_L = packing line pressure along edges, not to be taken less than 50 N/cm.

For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

4.3.12 The buckling strength of primary members is to be specially considered.

4.3.13 All load transmitting elements in the design load path from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks, *see* Section 2.

4.4.2 The design of the hinges for these doors should take into account the ship angle of trim or heel which may result in uneven loading of the hinges.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and support so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.5.2 Devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in a proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 acting on the maximum projected area in the open position.

4.5.5 The spacing for cleats or closing devices should not exceed 2,5 m and there should be cleats or closing devices positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.6 Systems for operation

4.6.1 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the vertical limit of watertight integrity with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the vertical limit of watertight integrity. This remote control is provided for the:

(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.6.2 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.6.3 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately the ship leaves the berth and that this operation is to be entered in the ship's log.

4.6.4 Means are to be provided to prevent unauthorized operation of the doors.

4.6.5 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.7 Systems for indication and monitoring

4.7.1 The following requirements apply to doors in the boundaries of special category spaces or vehicle spaces, through which such spaces may be flooded. For ships, where no part of the door is below the design waterline, doors that are to be opened at sea are above the vertical limit of watertight integrity, and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.7.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.7.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.7.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.8 Design loads

4.8.1 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$F_e = Ap_e + F_p$ kN
Internal force:
$F_i = F_o + 10W$ kN

(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$F_e = Ap_e$ kN
Internal force:
$F_i = F_o + 10W + F_p$ kN

(c) Design forces for primary members:
External force:
$F_e = Ap_e$ kN
Internal force:
$F_i = F_o + 10W$ kN
whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, in kN/m^2, determined at the centre of gravity of the door opening and is not to be taken less than:
for $Z_G < T$ $10\,(T - Z_G) + 25$ kN/m^2
for $Z_G \geq T$ 25 kN/m^2
For stern doors, p_e is not to be taken less than:
$p_{emin} = 0{,}6\lambda C_H\,(0{,}8 + 0{,}6\sqrt{L_R})^2$ kN/m^2

T = summer draught, in metres

Z_G = height of the centre of area of the door, in metres, above the baseline

L_R = length of ship, but need not be taken greater than 200 m

λ = coefficient depending on the area where the ship is intended to be operated:
= 1 for sea going ships with service area notation **SA1**, **SA2** and **SA3**
= 0,5 for ships operated in sheltered waters with service area notation **SA4**

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1 for $L_R \geq 80$ m

A = area, in m^2, of the door opening

W = weight of the door, in tonnes

F_p = total packing force, kN. When packing is fitted, the packing line pressure is to be specified, normally not to be taken less than 5 kN/m^2

F_o = the greater of F_c and $5{,}0A$ kN

F_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose items.

4.9 Design of securing and supporting devices

4.9.1 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:
The terms 'securing device' and 'supporting device' are defined in Section 3.

$$\tau = \frac{80}{k_s} \text{ N/mm}^2$$

$$\sigma = \frac{120}{k_s} \text{ N/mm}^2$$

$$\sigma_e = \frac{150}{k_s} \text{ N/mm}^2$$

4.9.2 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k} \text{ N/mm}^2$$

4.9.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0{,}8\sigma_o$, *see* 4.1.1. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.9.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.9.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.9.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.5.3 and taking account of the available space in the hull for adequate support.

4.9.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses as defined in 4.9.1.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections, repairs and renewals.

4.10.2 The Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.10.3 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks, lifts and ramps

5.1 Classification

5.1.1 At the Owner's or Builder's request movable decks will be included as a classification item, and the class notation Movable decks will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.1.2 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.1.3 The operating and securing equipment or machinery is to be in accordance with the requirements of the Naval Authority, *see* Pt 1, Ch 2,2.2.6

5.2 Arrangements and design

5.2.1 Positive means of control are to be provided to secure decks, ramps and lifts in the raised and lowered position.

5.2.2 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specifications.

5.2.3 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k$ N/mm^2.

5.3 Loading

5.3.1 Details of the deck, ramp or lift loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN. *See* Section 2.

5.3.2 Where it is proposed also to use the decks, ramps or lifts for general cargo, the design loadings are to be submitted for consideration.

5.3.3 The forces imposed on the decks, ramps or lifts are to take due account of the ship motion for all the conditions In which they will be operated, *see* Pt 5, Ch 3,6.2.

5.3.4 The scantlings and arrangements are to be not less than those required by the Rules for the supporting or surrounding structure in which the decks ramps or lifts are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.3.5 The buckling strength of primary members is to be verified as being adequate, *see* Pt 6, Ch 2,4.

5.3.6 Decks, ramps or lifts and their supporting structure are to be designed for the maximum load that is to be carried this may include loadings from emergency situations where they are defined by the Owner.

5.4 Movable decks

5.4.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.4.2 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.4.3 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.4.4 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during vehicle operations.

5.5 External deck ramps and lifts

5.5.1 In addition to the loading specified in 5.3, ramps and lifts are to be assessed using weather deck loading in the closed position, *see* Pt 5, Ch 3,5.

5.6 External shell ramps

5.6.1 In addition to the loading specified in 5.3, unprotected ramps are to be assessed using side shell loading in the closed position, *see* Pt 5, Ch 3,3.

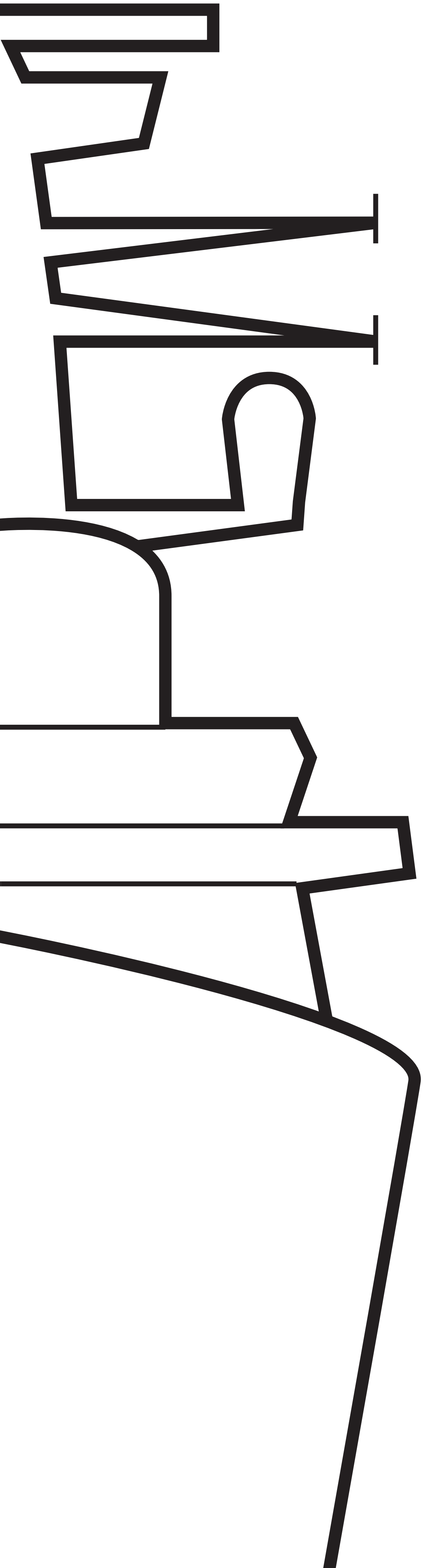
5.6.2 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 3.5. The shear, bending and equivalent stresses are not to exceed $80/k$ N/mm^2, $120/k$ N/mm^2 and $150/k$ N/mm^2 respectively.

5.7 Aircraft lifts

5.7.1 The aircraft lift platform deck alignment is to be provided by keeps at the flight deck and stops at the hanger deck.

5.7.2 If the ship has an underwater shock notation, latches are also to be provided at the flight and hanger deck levels to restrain the aircraft lift platform when stationary.

5.7.3 When transferring the aircraft or equipment to, or from, the lift platform with the keeps engaged the deflection of the platform edge is not to be greater than 25 mm.



Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 5*

Environmental loads

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Lloyd's Register

Chapter Contents

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■ *Section 1* Introduction

1.1 General

1.1.1 The global and local design loads and criteria detailed in this Part are to be used in conjunction with the formulae given in Part 6 to determine the scantlings of naval ships as defined in Part 1.

1.1.2 When appropriate, the load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as 'LR').

1.1.3 Alternative methods of establishing the load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also, they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Naval Ship Rules Software

2.2.1 LR's direct calculation procedures and facilities are summarised in a publication entitled the *LR Software Guide*.

2.3 Submission of direct calculations

2.3.1 In cases where direct calculations have been carried out the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the direct calculation model.
(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.3.2 In general, all input data and output results are required to be submitted. In such cases, electronic transferral of data with agreed format may be used for submission.

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct interpretation of output rests with the designer/Builder.

■ *Section 3* Model experiments

3.1 General

3.1.1 LR may require model experiments and theoretical calculations to be carried out for novel or complex design concepts. It is advisable that details of all proposed model experiments and theoretical calculations are submitted to LR prior to commencement of the testing and analysis phases. The results of all such investigations are to be provided no later than when plans are submitted for approval, but preferably as early as possible.

3.1.2 Where model testing is undertaken, the following details are to be submitted:

(a) a summary of the model construction and its instrumentation, including calibration of instruments;
(b) a summary of the testing arrangements and procedures;
(c) a summary of the tank facilities and test equipment;
(d) details of the wave generation, response measurements, definitions and notations;
(e) details of data recording, data reduction and data analysis procedures;
(f) details of calibration procedures with theoretical computations; and
(g) tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in Table 1.3.1 is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas, using the wave environment details in Chapter 2.
Heading	Beam, head, stern and bow and stern quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave Frequency	Six frequencies for regular seas

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data is to be obtained where appropriate:

(a) vertical accelerations at the LCG, bow and stern;
(b) acceleration loads due to heave, pitch and roll;
(c) vertical bending moment;
(d) bow impact pressures at representative operational forward speeds;
(e) oblique sea loads inducing horizontal bending moments and torsional moments.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval at the earliest opportunity.

3.2.4 Results from open water model experiments and full scale measurements may be accepted, full details are to be submitted for appraisal.

■ *Section 1* General

1.1 Introduction

1.1.1 This Chapter contains information regarding the environmental conditions to be applied in the derivation of loads that are to be used for the computation of the local and global design loads in Chapters 3 and 4.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents and also ice and thermal conditions.

1.1.3 The environmental conditions given here are derived from hindcast data, long term measurements and theoretical studies complemented with service experience.

1.1.4 Alternative methods of establishing the environmental conditions will be specially considered, provided that they are based on hindcast data, long term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

1.1.5 In order that an assessment of the design requirements can be made, the following information is to be submitted:

(a) Service area notation required together with the required extent of the operational area.
(b) The wave environmental parameters for the design.
(c) Specification of the environmental conditions used for the design assessment.

1.2 Definitions and symbols

1.2.1 **Beaufort Number**. Beaufort Number is a measure of wind strength. The wind speed corresponding to each Beaufort number is shown in Table 2.1.1.

1.2.2 **Sea state**. Sea state is an expression used to categorise wave conditions and is normally defined by a significant wave height and wave period, a suitable wave energy distribution may also be defined. A list of standard sea state definitions is shown in Table 2.1.2.

1.2.3 **Wave period**. References to wave period are to be taken as the zero crossing wave period, i.e. the average time interval between upward crossings of the mean value, unless otherwise stated.

1.2.4 L_{WL} is defined in Pt 3, Ch 1,5.2.

Table 2.1.1 Wind data

Beaufort number	Wind speed range knots
0	0–1
1	1–3
2	4–6
3	7–10
4	11–16
5	17–21
6	22–27
7	28–33
8	34–40
9	41–47
10	48–55
11	56–63

Table 2.1.2 Sea state data

Sea State Number	Significant Wave height(m)		Sustained Wind Speed (Knots) (*See* Note 1)		Percentage probability of sea state	Modal Wave Period (sec)	
	Range	Mean	Range	Mean		Range (*see* Note 3)	Most probable
0–1	0–0,1	0,05	0–6	3	0,7	—	—
2	0,1–0,5	0,3	7–10	8,5	6,8	3,3–12,8	7,0
3	0,5–1,25	0,88	11–16	13,5	23,7	5,0–14,8	7,5
4	1,25–2,5	1,88	17–21	19	27,8	6,1–15,2	8,8
5	2,5–4	3,25	22–27	24,5	20,64	8,3–15,5	9,7
6	4–6	5	28–47	37,5	13,15	9,8–16,2	12,4
7	6–9	7,5	48–55	51,5	6,05	11,8–18,5	15,0
8	9–14	11,5	56–63	59,5	1,11	14,2–18,6	16,4
>8	>14	>14	>63	>63	0,05	18,0–23,7	20,0

NOTES
1. Ambient wind sustained at 19,5 m above surface to generate fully-developed seas.
2. To convert to another altitude, H_2, apply $V_2 = V_1 (H_2/19,5)^{(1/7)}$
3. Minimum is 5 per cent and maximum is 95 per cent for periods given wave height range.
4. The wave period shown here is the modal or peak period, T_p. The zero crossing period, T_z, may be derived by the expression $T_z = T_p/1,4$ for fully developed seas.

Section 2 Wave environment

2.1 General

2.1.1 Generally ships of Naval Ship Groups 1 and 2, **NS1** and **NS2**, *see* Pt 1, Ch 2,2.1 will be designed for unrestricted world-wide operation. Ships in group 3, **NS3**, may also be designed for world-wide operation but typically will be designed for more specific roles within clearly defined areas of operation, e.g., coastal patrol craft, landing craft, harbour vessels, tugs, etc.

2.1.2 The procedure for deriving the design factors and the wave environment used for the assessment of local and global loads is illustrated in Fig. 2.2.1.

2.1.3 The following definitions are applicable:

Service area
A service area refers to a collective group of sea areas. The service area specifies the limits of the ship's operational area.

Sea area
A sea area is small area of the world's oceans for which statistical wave data has been collected, the sea areas are shown in Fig. 2.2.2.

2.2 Service areas

2.2.1 All ships classed under the Rules will be assigned a service area notation **SA** followed by a number or letter, e.g. **SA1**.

2.2.2 The service area notations listed below are available. The definitive extents of the service areas are shown in Fig. 2.2.2 and Table 2.2.3. The chart shows the minimum service area requirement for operating in different areas of the world.

SA1 Service Area 1 covers ships having unrestricted world-wide operation. Service area 1 includes operation in all other service areas.

SA2 Service Area 2 is primarily intended to cover ships designed to operate in tropical and temperate regions, *see* 2.2.3. This service area excludes operating in sea areas for which a **SA1** notation is required.

SA3 Service Area 3 is primarily intended to cover ships designed to operate in tropical regions, *see* 2.2.3. This service area excludes operating in sea areas for which a **SA1** or **SA2** notation is required.

SA4 Service Area 4 covers ships designed to operate in Sheltered water, as defined in Pt 1, Ch 2,2.2. This service area excludes operating in sea areas for which a **SA1**, **SA2** or **SA3** notation is required.

SAR Service Area Restricted covers ships that are designed to operate in a predetermined and contiguous area of operation, *see* 2.2.4.

2.2.3 For all ships that are designed for specific areas of operation, the designer may take advantage of reduced wave loadings that are likely to be encountered. This covers all ships which are assigned a service area notation **SA2**, **SA3**, **SA4** or **SAR**.

2.2.4 For all cases where a **SAR** service area notation (Service Area Restricted) is required, the extents of the restricted area will be specified after the **SAR** service area notation. The service area factor, f_s, and the wave environment characteristics for the ship will be specially considered. Where the geographical limits of the intended service can be satisfied by a single or group of contiguous sea areas then the service area factor, f_s, and the wave environment characteristics may be derived using the methods given in 2.4 and 2.5.

2.2.5 Under normal circumstances, a ship which is assigned a service area notation **SA2**, **SA3**, **SA4** or **SAR** is to operate in solely the designated area and is not transit to other areas of the world, *see* Pt 1, Ch 2,1.1. Due allowance is to be made for the ship's trials, work-up period and delivery voyages in the assignment of a service area notation. However special consideration may be appropriate to these periods in order to ensure that the ship is not subjected to dynamic loads which might impair the structural working life of the ship.

2.2.6 The wave environmental data for service areas **SA1**, **SA2**, **SA3** and **SA4** are specified in 2.3.

2.2.7 The Owner or builder should confirm that the chosen Service Area, the service area factor, f_s, and the wave environment characteristics as defined in 2.3 are appropriate for the intended areas of operation.

2.2.8 The allocation of a service area notation to a ship does not remove the responsibility of the master or commanding officer to take suitable measures to avoid typhoon, hurricane and other extreme weather conditions, as appropriate.

2.2.9 The requirements for ships which are required to maintain station or operate in typhoon, hurricane and other extreme weather conditions will be specially considered.

2.3 Wave environment

2.3.1 The environmental wave data for each service area notation is given in Table 2.2.1. Table 2.2.4 gives the environmental wave data for each individual sea area.

2.3.2 The definitions of wave height, wave period and wave period range given below are to be used in the determination of the environmental loads acting on the ship.

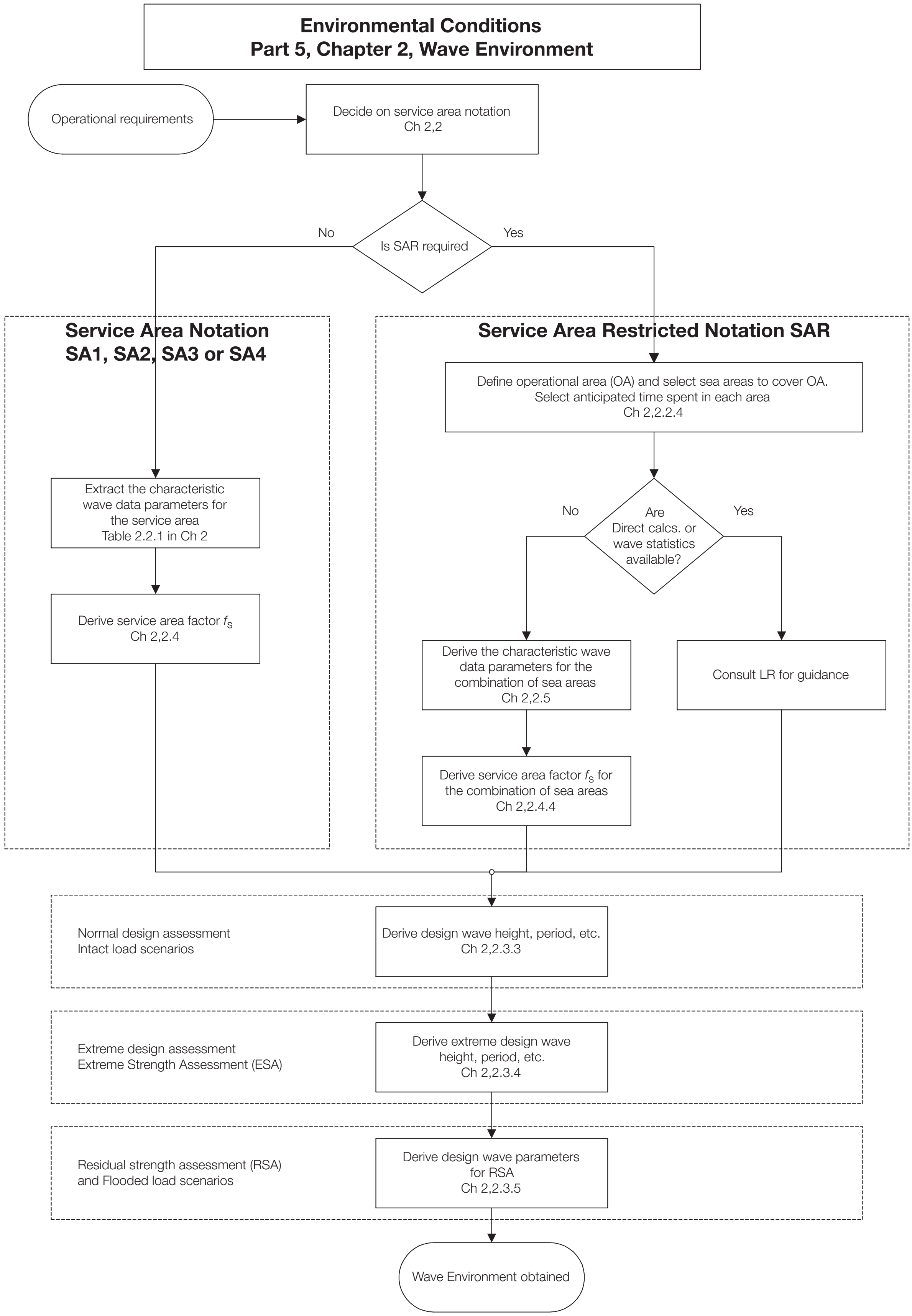
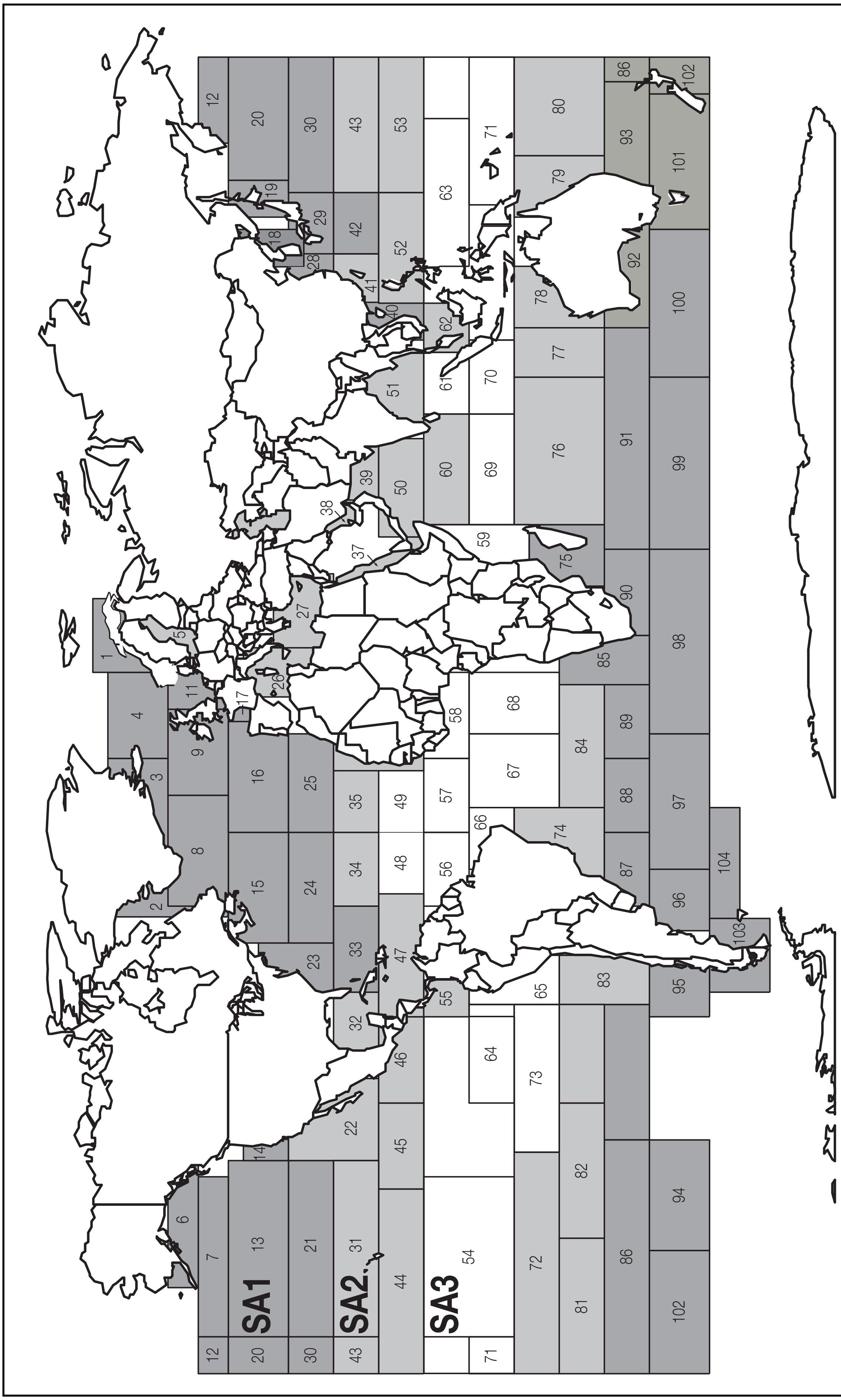


Fig. 2.2.1 Procedure for the specification of environmental conditions



Service Area Definitions
Chart shows the minimum required service area notation for each sea area

Fig. 2.2.2 Sea areas

Table 2.2.1 Environmental wave data for each service area

Service Area Notation	Wave height for the service area, in metres	Mean wave period, in seconds	Standard deviation of wave period, in seconds	Extreme design wave height, in metres
	H_s	T_z	T_{sd}	H_x
SA1	5,5	8,0	1,7	18,5
SA2	4,0	7,0	1,7	13,5
SA3	3,6	6,8	1,7	9,5
SA4	2,5	6,0	1,5	6,0
SAR	To be specially considered			
NOTE *See* text and notes in Table 2.2.4 for definitions of all values.				

2.3.3 Wave environmental design criteria for normal design assessment. These design parameters have been used to derive the standard local and global environmental loadings in Chapters 3 and 4. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Design wave height, H_{dw}
Average of the one hundredth highest observed wave heights for the service area. To be taken as:
$H_{dw} = 1,67H_s$ m

Design wave period, T_{dw}
Average zero crossing period of all seastates in the service area
$T_{dw} = T_z$ seconds

Standard deviation of wave period, T_{dsd}
Standard deviation of the zero crossing periods for the service area
$T_{dsd} = T_{sd}$ seconds

Design wave period range, T_{drange}
To be taken as the design wave period plus and minus 2 standard deviations of the zero crossing period, i.e.
T_{drange} is $T_{dw} - 2T_{dsd}$ to $T_{dw} + 2T_{dsd}$ seconds

H_s, T_z, and T_{sd} are given in 2.3.6.

2.3.4 Wave environmental design criteria for extreme design analysis, **ESA** notations. These design parameters have been used to derive the global environmental loadings in Chapter 4 which are used for the extreme strength assessment notation. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Extreme wave height, H_{xw}
To be taken as the significant wave height that has a probability of 5 x 10^{-5} of being exceeded.
$H_{xw} = H_x$ m

Extreme wave period, T_{xw}
To be taken as the design wave period plus one standard deviation
$T_{xw} = T_{dw} + T_{dsd}$ seconds

Extreme wave period range, T_{xrange}
To be taken as the extreme design wave period plus and minus 1,5 standard deviations
T_{xrange} is $T_{xw} - 1,5T_{dsd}$ to $T_{xw} + 1,5T_{dsd}$ seconds

Duration of extreme storm
It is to be assumed that extreme storm events are to persist for three hours.

T_{sd} and H_x are given in 2.3.6
T_{dw} and T_{dsd} is given in 2.3.3.

2.3.5 Wave environmental design criteria for residual strength analysis, **RSA** notations. These design parameters have been used to derive the global and local environmental loadings in Chapters 3 and 4 which are used for the residual strength assessment notation. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Residual wave height, H_{rw}
To be taken as the significant wave height that has a 20 per cent probability of being exceeded for the service area
$H_{rw} = 0,90H_s$ m

Residual wave period, T_{rw}
To be taken as the standard design wave period
$T_{dw} = T_z$ seconds

Residual wave period range, T_{rrange}
To be taken as the standard design wave period range
$T_{rrange} = T_{drange}$ seconds

Duration of sea state
It is to be assumed that the duration of sea states of this magnitude is 12 hours.

H_s and T_z are given in 2.3.6
T_{drange} is given in 2.3.3.

2.3.6 The parameters used in above equations are given in Table 2.2.1 for service area notations **SA1**, **SA2**, **SA3** and **SA4**. For the restricted service area notation **SAR**, the values of H_s, T_z, T_{sd} and H_x will need to be derived, *see* 2.5.

2.4 Service Area factors

2.4.1 The service area factor, f_s, is used to derive the global hull girder loads in Chapter 4. The service area factor applicable for Service Area notations **SA1**, **SA2**, **SA3** and **SA4** is given by:

$$f_s = (f_1 + f_2 (L_{WL} - 100) /1000)\, f_{sl}$$

where
f_s is to have a minimum value of 0,5 and normally a maximum value of 1,0 and is to be rounded up to the nearest 0,05
f_{sl} is the service life factor as defined in 2.4.2
f_1 and f_2 are given in Table 2.2.2
L_{WL} is defined in Pt 3, Ch1,5.2.

2.4.2 The service life factor, f_{sl}, is based on a ship's operational life. This factor may need to be increased for service lives which are predicted to require significantly more wave encounters. The service life factor is to be taken as follows:

f_{sl} = 1,0 for 1 x 10^8 wave encounters (20 years)
= 1,010 for 1,25 x 10^8 wave encounters (25 years)
= 1,019 for 1,5 x 10^8 wave encounters (30 years).

Table 2.2.2 Environmental wave data for service area

Service Area Notation	Intercept factor f_1	Slope factor f_2
SA1	1,00	0,00
SA2	0,93	–1,15
SA3	0,70	–1,00
SA4	0,50	0,00
SAR	To be specially considered	

2.4.3 For unrestricted sea-going service, i.e. service area notation **SA1**, the service area factor is to be taken as 1,0.

2.4.4 Alternatively the service area factor may be derived by direct calculation of the long term hull girder loads, *see* Ch 4,1.3.

2.4.5 For restricted Service Area Notation **SAR** the service area factor is to be derived by combining the service areas factors for each sea area using the following formula:

$$f_s = \ln\left(\sum_{i=1}^{n} P_i \, e^{f_{si}}\right)$$

where

$f_{si} = f_{1i} + f_{2i}\,(L_{WL} - 100)/1000$

f_{1i} and f_{2i} are the individual sea area factors given in Table 2.2.3

$e = 2{,}7183$

ln ( ) is the natural log

P_i is defined in 2.5.3.

2.5 Derivation of wave statistics for a combination of sea areas

2.5.1 For the **SAR** restricted service area notation, it is necessary to derive the environmental wave data for the required area of operation. This data may be determined using statistical methods as specified in 2.6 or using the information given in this Section.

2.5.2 The following formulae may be used to derive the design wave statistics for a ship designed to operate with a particular service area restriction. These formulae enable the environmental wave data from a set of individual sea areas to be combined to give the appropriate design wave statistics for the **SAR** restricted service area notation, *see also* 2.2.

2.5.3 The environmental wave data for each sea area is given in Table 2.2.4. The extents of each sea area are shown in Fig. 2.2.2.

Wave height, H_s

H_s = weighted average of the wave height for all sea areas plus one standard deviation

$$= H_{sm} + \sqrt{\sum_{i=1}^{n} P_i\,(H_{si} - H_{sm})^2} \quad \text{m}$$

where

$$H_{sm} = \sum_{i=1}^{n} P_i\,H_{si} \quad \text{m}$$

Design wave period, T_{dw}

T_{dw} = weighted average of the wave period for all sea areas

$$= \sum_{i=1}^{n} P_i\,T_{zi} \quad \text{seconds}$$

Standard deviation of wave period, T_{sd}

T_{sd} = weighted average of the standard deviation for all sea areas about the combined design wave period, T_{dw}

$$= \sqrt{\sum_{i=1}^{n} P_i\,(T_{sdi}^2 + (T_{dw} - T_{zi})^2)} \quad \text{seconds}$$

Extreme wave height, H_x

H_x = weighted average of the extreme wave height for all sea areas plus one standard deviation

$$= H_{xm} + \sqrt{\sum_{i=1}^{n} P_i\,(H_{xi} - H_{xm})^2} \quad \text{m}$$

where

$$H_{xm} = \sum_{i=1}^{n} P_i\,H_{xi} \quad \text{m}$$

where

N is the number of sea areas

i is the sea area index reference

P_i is the probability of the ship operating in sea area i, i.e. the percentage of time, expressed as a probability value

H_{si} is the appropriate sea area wave height value for sea area i

H_{xi} is the appropriate extreme wave height value for sea area i

T_{zi} is the appropriate zero crossing period for sea area i

T_{sdi} is the appropriate standard deviation for sea area i

2.5.4 The designer/Builder is to supply full details of the **SAR** notation required together with full supporting calculations. All transit voyages and ship work-up/trial periods should be included in the list of sea areas if their inclusion results in a more severe wave environment, *see also* 2.2.5.

2.6 Direct calculations

2.6.1 The wave environmental parameters may be derived by direct calculation using long term statistical wave data for the selected area(s) of operation based on hindcast data or similar analysis. This data is to accurately represent the sea environment in the intended area of operation over a long period and enable sound long term and extreme short term statistics to be derived. Depending on the area of operation, due account is to be taken of typhoon, hurricane and other seasonal extremes, *see also* 2.2.8.

Table 2.2.3 Environmental wave data for individual sea area

Sea Area No.	Minimum service area notation required to operate in this sea area	Intercept factor f_{1i}	Slope factor f_{2i}	Sea Area No.	Minimum service area notation required to operate in this sea area	Intercept factor f_{1i}	Slope factor f_{2i}
1	SA1	1,13	–1,97	51	SA2	0,82	–1,89
2	SA2	0,94	–1,81	52	SA2	0,87	–1,43
3	SA1	1,13	–1,97	53	SA2	0,74	–0,84
4	SA1	1,01	–1,01	54	SA3	0,62	–0,65
5	SA3	0,72	–1,85	55	SA2	0,78	–0,97
6	SA1	1,08	–1,33	56	SA3	0,63	–0,71
7	SA1	0,89	–0,16	57	SA3	0,56	–0,77
8	SA1	0,98	0,17	58	SA3	0,57	–1,13
9	SA1	1,00	0,02	59	SA3	0,69	–1,15
10	SA1	1,11	–1,80	60	SA2	0,87	–1,43
11	SA1	1,18	–2,56	61	SA3	0,69	–1,15
12	SA1	1,19	–1,44	62	SA2	0,85	–2,13
13	SA1	0,96	–0,48	63	SA3	0,69	–1,31
14	SA1	0,96	–0,81	64	SA3	0,59	–0,55
15	SA1	1,01	–0,34	65	SA3	0,55	–0,43
16	SA1	1,00	0,02	66	SA3	0,59	–0,55
17	SA1	1,03	–0,64	67	SA3	0,63	–0,71
18	SA1	1,11	–3,45	68	SA3	0,65	–0,83
19	SA1	1,10	–1,52	69	SA3	0,68	–0,97
20	SA1	1,10	–0,83	70	SA3	0,67	–0,58
21	SA1	0,88	–0,53	71	SA3	0,69	–1,50
22	SA2	0,80	–1,29	72	SA2	0,63	–0,32
23	SA1	1,00	–1,65	73	SA3	0,64	–0,33
24	SA1	1,01	–0,50	74	SA2	0,74	–0,84
25	SA1	0,90	–0,42	75	SA1	0,85	–0,65
26	SA2	0,98	–2,43	76	SA2	0,77	–0,19
27	SA2	0,98	–2,43	77	SA2	0,79	–0,20
28	SA2	0,98	–2,43	78	SA2	0,86	–0,98
29	SA1	1,06	–2,05	79	SA2	0,87	–1,42
30	SA1	1,01	–0,50	80	SA2	0,78	–0,56
31	SA2	0,74	–0,44	81	SA2	0,79	–0,20
32	SA2	0,82	–1,89	82	SA2	0,74	–0,44
33	SA1	0,75	–1,01	83	SA2	0,75	–0,58
34	SA2	0,78	–0,70	84	SA2	0,73	–0,69
35	SA2	0,73	–0,76	85	SA1	0,80	–0,15
36	SA2	0,75	–1,16	86	SA1	0,89	–0,26
37	SA3	0,72	–1,85	87	SA1	0,91	–0,51
38	SA3	0,69	–2,13	88	SA1	0,89	–0,16
39	SA2	0,85	–2,14	89	SA1	0,98	–0,08
40	SA1	1,05	–1,97	90	SA1	0,98	–0,08
41	SA1	1,00	–1,65	91	SA1	0,98	–0,08
42	SA2	0,98	–1,31	92	SA1	0,90	0,09
43	SA2	0,78	–0,54	93	SA1	0,90	–0,32
44	SA2	0,78	–0,54	94	SA1	0,98	0,31
45	SA2	0,64	–0,34	95	SA1	0,89	–0,16
46	SA2	0,75	–1,22	96	SA1	1,00	–0,91
47	SA2	0,75	–1,01	97	SA1	0,98	0,16
48	SA3	0,65	–0,78	98	SA1	0,89	0,21
49	SA3	0,68	–0,94	99	SA1	0,98	0,30
50	SA2	1,09	–2,70	100	SA1	1,03	0,52
				101	SA1	0,98	–0,18
				102	SA1	0,89	–0,16
				103	SA1	1,06	–0,23
				104	SA1	0,89	–0,26

2.6.2 The derivation of the wave environmental parameters is to be in accordance with the data specification and methods given in 2.3. The areas used for the direct calculation will then be specified after the **SAR** service area restriction notation.

Table 2.2.4 Environmental wave data for each sea area

Sea Area No.	Sea area wave height, in metres H_{si}	Mean wave period, in seconds T_{zi}	Standard deviation of wave period, in seconds T_{sdi}	Extreme design wave height, in metres H_{xi}	Sea Area No.	Sea area wave height, in metres H_{si}	Mean wave period, in seconds T_{zi}	Standard deviation of wave period, in seconds T_{sdi}	Extreme design wave height, in metres H_{xi}
1	3,6	6,4	1,3	16,9	53	3,7	7,5	1,5	10,0
2	3,0	6,2	1,3	12,5	54	3,5	7,7	1,5	8,9
3	4,3	7,5	1,4	17,6	55	2,5	6,2	1,3	7,4
4	4,4	7,4	1,4	16,2	56	3,4	7,4	1,5	8,6
5	2,5	5,2	1,1	8,6	57	3,1	7,1	1,5	7,8
6	4,2	7,4	1,4	15,6	58	2,5	6,1	1,3	7,1
7	5,0	8,4	1,5	15,4	59	2,9	6,3	1,3	9,2
8	5,5	8,6	1,5	18,4	60	3,0	6,3	1,3	11,5
9	5,3	8,5	1,5	18,2	61	3,0	6,5	1,3	9,0
10	3,7	6,7	1,3	15,8	62	2,5	5,5	1,2	11,0
11	3,4	6,1	1,2	17,0	63	2,7	6,2	1,3	8,4
12	5,0	7,8	1,4	18,3	64	3,4	7,5	1,5	8,2
13	4,8	8,3	1,5	16,2	65	2,9	7,1	1,5	8,2
14	4,0	7,7	1,5	14,5	66	3,4	7,3	1,5	8,1
15	4,7	8,0	1,4	17,9	67	3,5	7,4	1,5	8,9
16	5,2	8,4	1,5	19,2	68	3,5	7,2	1,4	8,7
17	4,3	7,8	1,4	18,3	69	3,2	7,2	1,5	9,2
18	2,7	4,9	1,0	14,5	70	3,4	7,6	1,5	9,7
19	3,8	7,0	1,4	17,5	71	2,5	5,9	1,3	8,3
20	4,8	8,0	1,4	18,4	72	3,6	7,7	1,5	9,5
21	4,4	8,1	1,5	14,0	73	4,0	8,0	1,5	9,4
22	3,3	7,0	1,4	10,7	74	3,3	7,2	1,4	10,6
23	3,4	6,5	1,3	15,2	75	3,9	7,8	1,5	13,0
24	4,6	8,0	1,5	17,4	76	4,4	8,2	1,5	12,5
25	4,4	8,1	1,5	14,5	77	4,6	8,3	1,5	12,6
26	2,7	5,5	1,2	13,6	78	3,8	7,6	1,5	12,0
27	2,6	5,6	1,2	13,2	79	3,3	6,5	1,3	11,2
28	2,8	5,5	1,1	12,4	80	3,7	7,7	1,5	12,2
29	3,4	6,3	1,3	15,5	81	4,4	8,2	1,5	12,7
30	4,7	8,2	1,5	16,8	82	4,1	8,0	1,5	11,3
31	3,8	7,8	1,5	11,5	83	3,8	7,8	1,5	11,2
32	2,8	5,8	1,2	10,0	84	4,3	8,2	1,5	10,8
33	3,2	6,8	1,4	11,5	85	4,9	8,4	1,5	13,3
34	3,6	7,6	1,5	11,5	86	4,6	8,2	1,5	15,7
35	3,9	7,9	1,5	10,3	87	3,8	7,7	1,5	16,8
36	3,3	6,9	1,4	9,5	88	5,0	8,5	1,5	15,3
37	2,3	5,1	1,1	8,5	89	4,8	8,3	1,5	18,2
38	1,8	4,5	0,9	8,3	90	5,2	8,5	1,5	17,9
39	2,5	5,2	1,1	10,5	91	5,4	8,6	1,5	17,7
40	3,5	6,3	1,2	13,4	92	5,2	8,5	1,5	16,7
41	3,7	6,6	1,3	14,0	93	4,2	8,0	1,5	15,3
42	3,6	6,9	1,4	15,2	94	6,0	8,9	1,4	17,7
43	4,1	7,9	1,5	12,1	95	5,5	8,7	1,5	14,6
44	4,0	8,0	1,5	10,1	96	4,0	7,5	1,4	16,9
45	3,7	7,8	1,5	9,5	97	5,6	8,7	1,5	17,3
46	2,8	6,4	1,3	10,7	98	5,6	8,7	1,5	16,7
47	3,4	6,6	1,3	10,0	99	6,1	9,0	1,4	18,0
48	3,6	7,6	1,5	9,2	100	6,0	8,9	1,4	20,1
49	3,5	7,3	1,4	9,0	101	4,9	8,4	1,5	17,1
50	3,1	5,8	1,2	14,1	102	4,8	8,3	1,5	16,5
51	2,7	5,8	1,2	10,4	103	5,3	8,5	1,5	18,2
52	3,2	6,5	1,3	12,2	104	4,7	8,2	1,5	16,6

NOTES
1. The sea area wave height H_{si} and wave zero crossing period, T_{zi}, are based on the annual, all directions wave data scatter diagram.
2. The sea area wave height H_{si} is the average of the one third highest observed (or significant) wave heights in the wave scatter diagram.
3. The T_{zi} and standard deviation of T_{sdi} are derived using all wave heights in the wave data scatter diagram.
4. The extreme design wave height, H_{xi}, is based on a Gumbel projection using the following data set definition:
   A wave data scatter diagram based on integer parts per ten thousand. *(Note using a higher precision scatter diagram will result in a higher estimate of extreme wave height)*.
   Probability of exceedance of 5 x10^{-5}, roughly equivalent to 6,5 years continuously at sea in each sea area.
5. The values of H_{si}, T_{zi}, and T_{sdi} were derived from the data set used for the extreme wave height.

■ *Section 3*
Air environment

3.1 Wind speed

3.1.1 For design purposes a wind speed of 40 m/s is to be assumed.

3.2 Design air temperature

3.2.1 The design air temperature is to be taken as 2°C lower than the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years (MDHT)

Average = average during one day and one night (MDAT)

Lowest = lowest during the year (MDLT).

Fig. 2.3.1 shows the definition graphically.

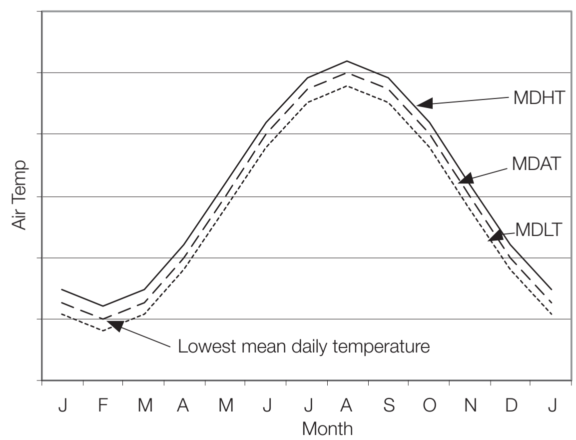


Fig. 2.3.1 Design air temperature

■ *Section 4*
Guidance for ice environment

4.1 General

4.1.1 This section is intended to give guidance on the selection of a suitable ice class notation for the operation of naval ships in Arctic and Antarctic regions.

4.1.2 The Owner is to confirm which notation is most suitable for their requirements. Ultimately the responsibility rests with the commanding officer and their assessment of the ice and temperature conditions at the time.

4.1.3 The documentation supplied to the ship is to contain the ice class notation adopted, any operation limits for the ship and guidance on the type of ice that can be navigated for the nominated ice class.

4.2 Definitions

4.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in Table 2.4.1.

Table 2.4.1 WMO definition of ice conditions

Ice conditions	Ice thickness
Medium first year	1,2 m
Thin first year, second stage	0,7 m
Thin first year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

4.2.2 Table 2.4.2 defines the ice classes in relation to the Rules and the equivalent internationally recognized standards.

Table 2.4.2 Comparison ice standards

Lloyd's Register class notation	Finish-Swedish Ice-Due class	Canadian type
1AS	IA Super	A
1A	IA	B
1B	IB	C
1C	IC	D
1D	ID	—
none	none	E

4.2.3 Extended periods are defined as those that involve the vessel remaining in air temperatures below 0°C for more than one week.

4.3 Application

4.3.1 For naval ships intended for extended periods of operation in Arctic and Antarctic areas the suggested ice class is **1C**. For these operational limits, the materials used for hull construction are to be in accordance with Pt 6, Ch 6,2. If a higher ice class is proposed, material requirements are to be specially considered using a specified design air temperature as defined in 3.2.

4.3.2 For naval ships required to operate in multi year ice as defined by the Ice breaker region in Fig. 2.4.1 without an ice breaker escort, the requirements for ice class will be specially considered. Material requirements are to be in accordance with Pt 6, Ch 6,2 using a specified design air temperature as defined in 3.2.

4.3.3 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice flows and the ice edge for each season. Operation with Ice Class **1C** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with Ice Class **1A** may be possible up to 150 nm inside the medium first year ice shown depending on the severity of the winter. Operation up to the multi year ice is possible most years with Ice Class **1AS**.

4.3.4 Operation in the region between 7/10 and 1/10 in the arctic is possible with due care for ships with no ice class. For ships operating for extended periods in these areas it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for a non-ice class ship, the material requirements of Pt 6, Ch 6,2 are recommended.

4.4 Ice Class notations

4.4.1 Where the requirements of Vol 3, Pt 1, Ch 1 are complied with, the ship will be eligible for a special features notation as defined in Pt 1, Ch 2,3.8.

4.5 National Authority requirements

4.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. Table 2.4.2 gives the equivalence of National Authority requirements.

4.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice-Due Classes given in Table 2.4.2. For definition of Ice-Due Classes, *see* Finnish-Swedish Ice Class Rules, 1985.

4.5.3 Ships intending to navigate in the Canadian Arctic must comply with the Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353, in respect of which Lloyd's Register is authorised to issue Arctic Pollution Prevention Certificates.

4.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

4.6 Ice accretion

4.6.1 For ships intended to operate for extended periods in Arctic or Antarctic the build up of ice on exposed surfaces is to be considered.

4.6.2 As a minimum a full icing allowance is to be applied to vessels operating in the following areas, *see* Fig. 2.4.2.

- The area north of latitude 65°30'N, between longitude 28°W and the West coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in subparagraphs above.
- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

4.6.3 As a minimum a half icing allowance is to be applied to vessels operating in the winter seasonal areas as defined in the international convention for load lines.

4.6.4 The icing allowance it to be applied to the still water bending moment calculation in accordance with Pt 5, Ch 4,2 and in the local loading section for the appropriate areas in accordance with Pt 5, Ch 3,7.

4.6.5 The effects on stability of ice accretion are to be assessed in accordance with the stability standard identified by the Naval Authority.

4.7 Ice conditions

4.7.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the world wide web at

http//www.natice.noaa.gov/.

Information is supplied by regular assessment and survey by the naval ice centres patrols.

4.7.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their web site can be found at

http// www.ice-glaces.ec.gc.ca.

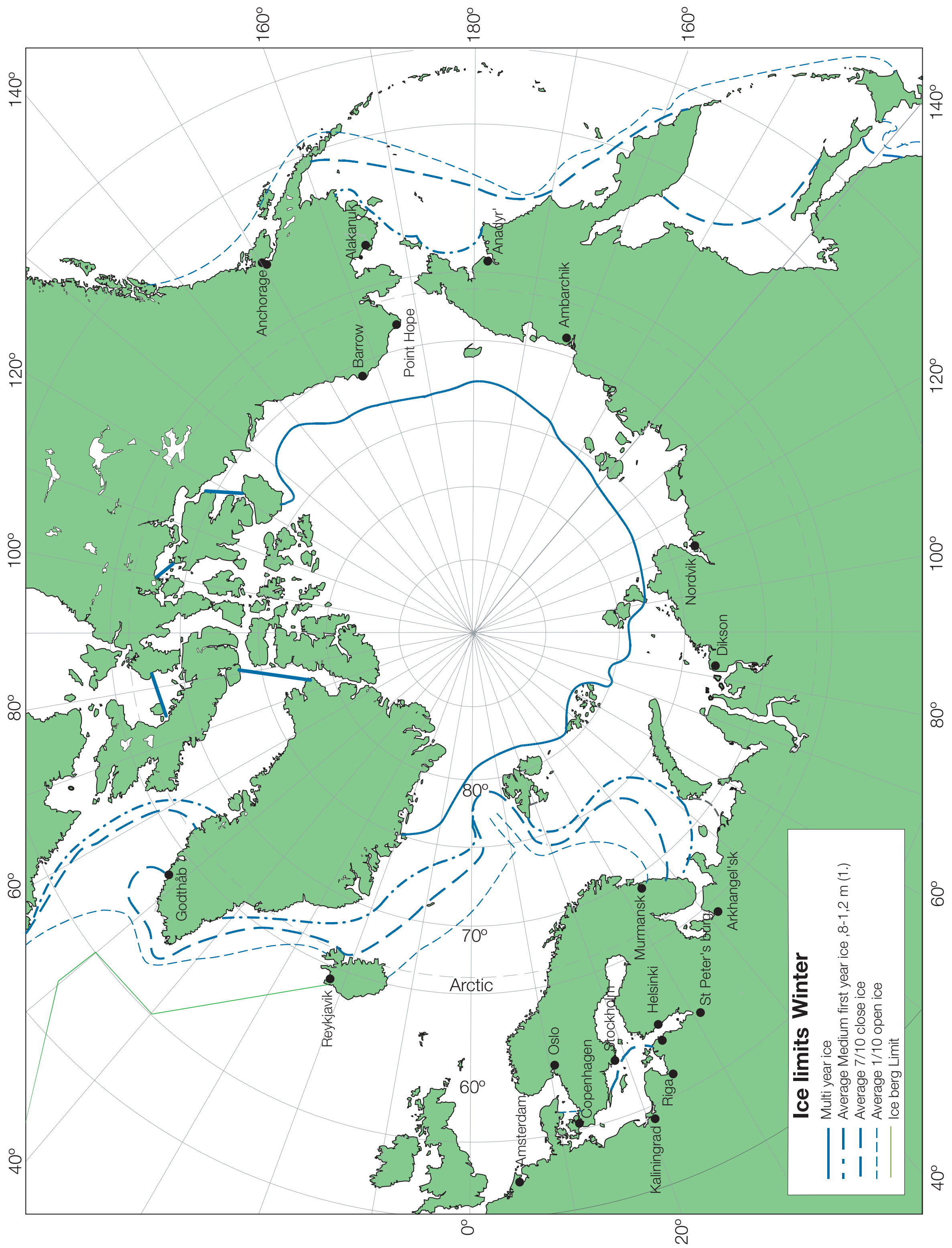


Fig. 2.4.1(a) Ice limit Arctic Winter

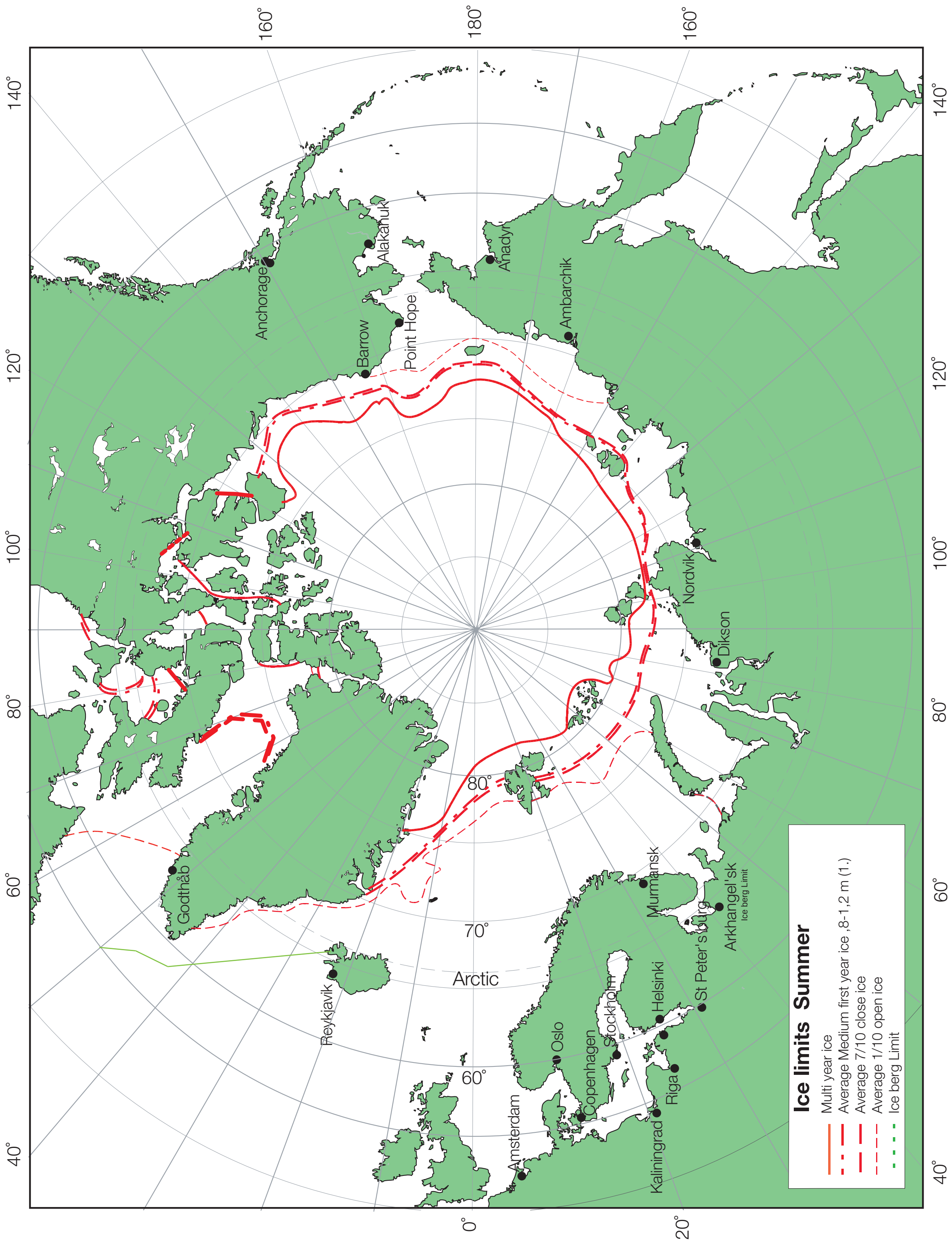


Fig. 2.4.1(b) Ice limits Arctic Summer

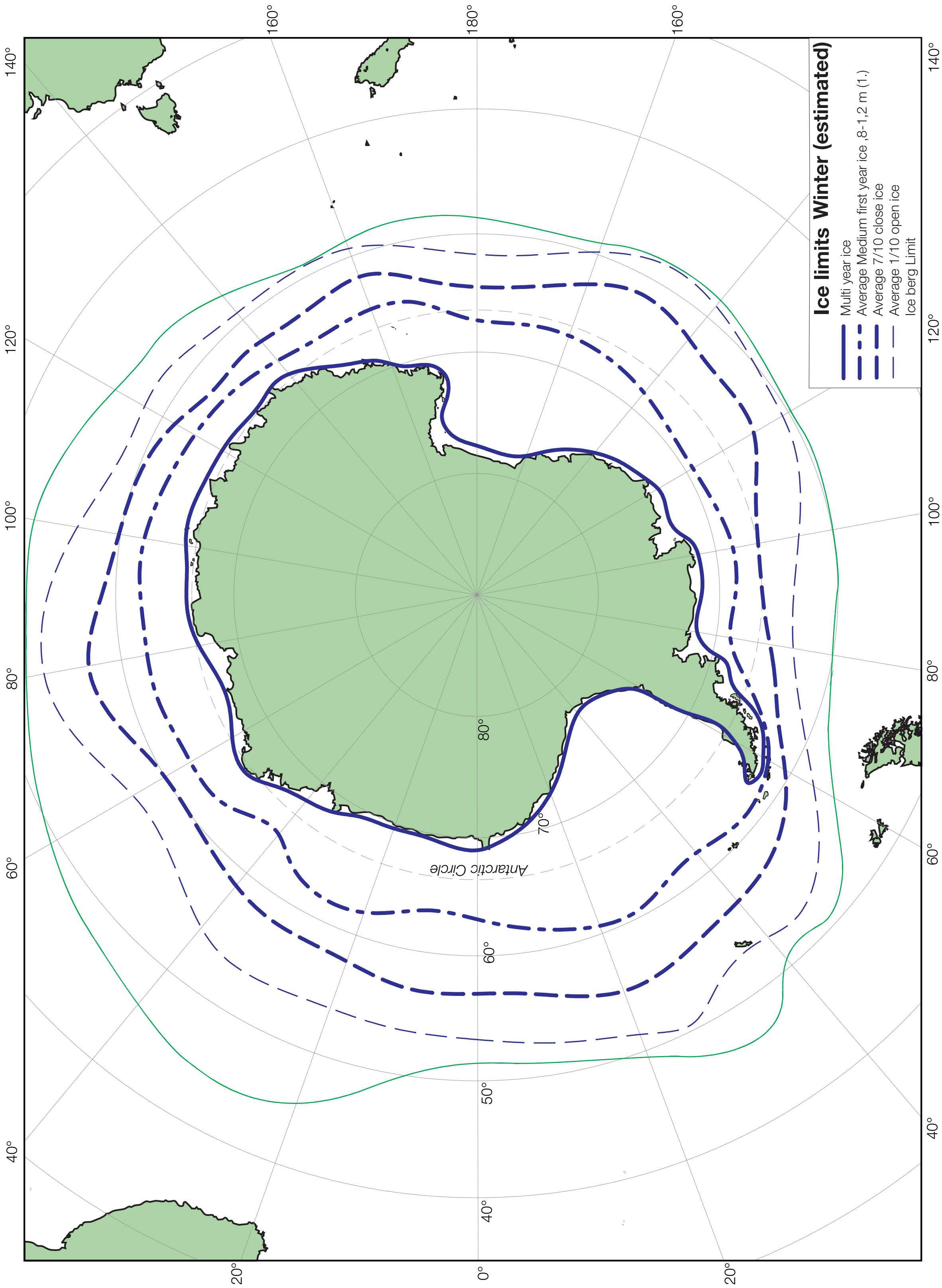


Fig. 2.4.1(c) Ice limit Antarctica Winter

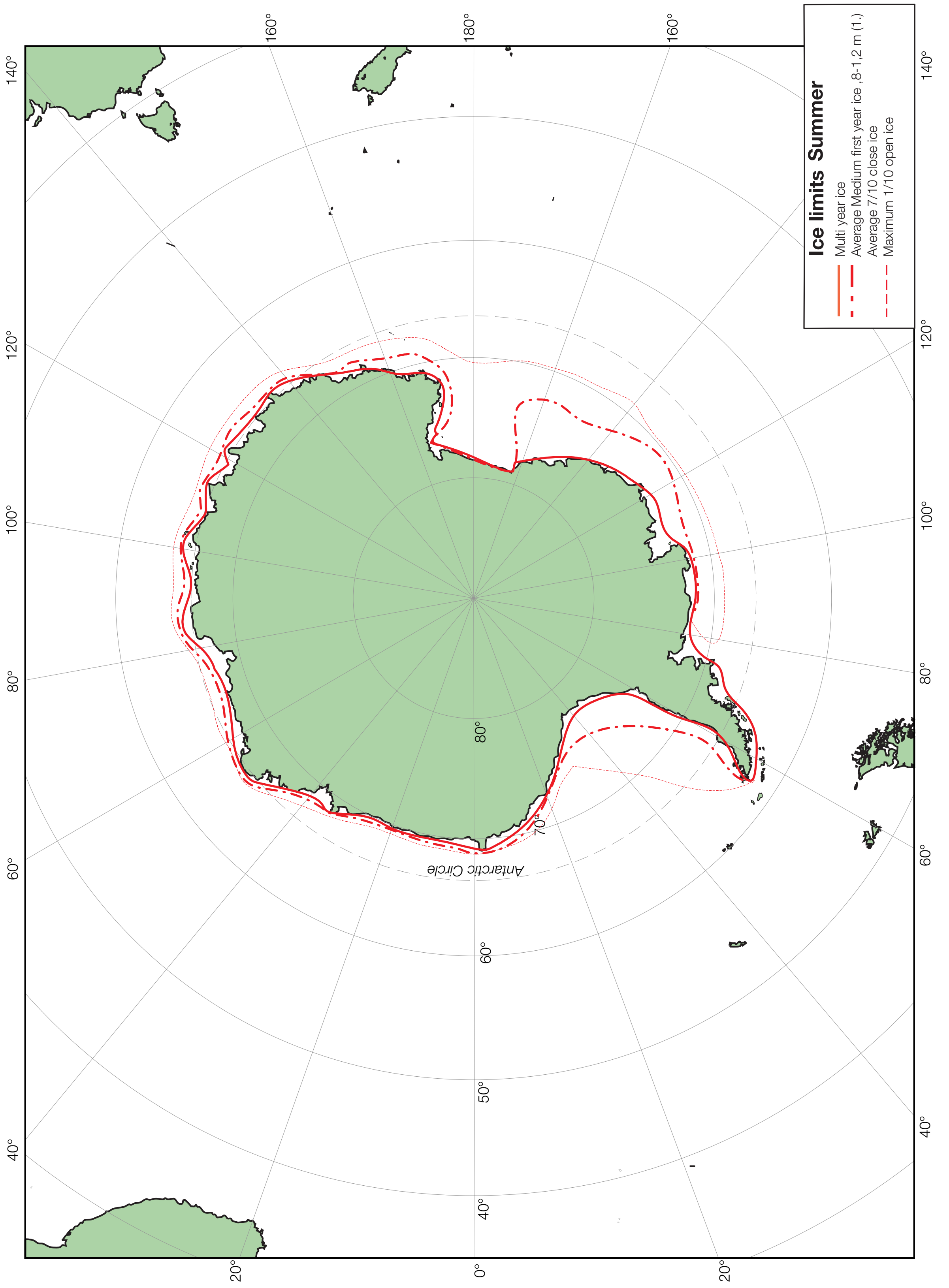


Fig. 2.4.1(d) Ice limits Antarctica Summer

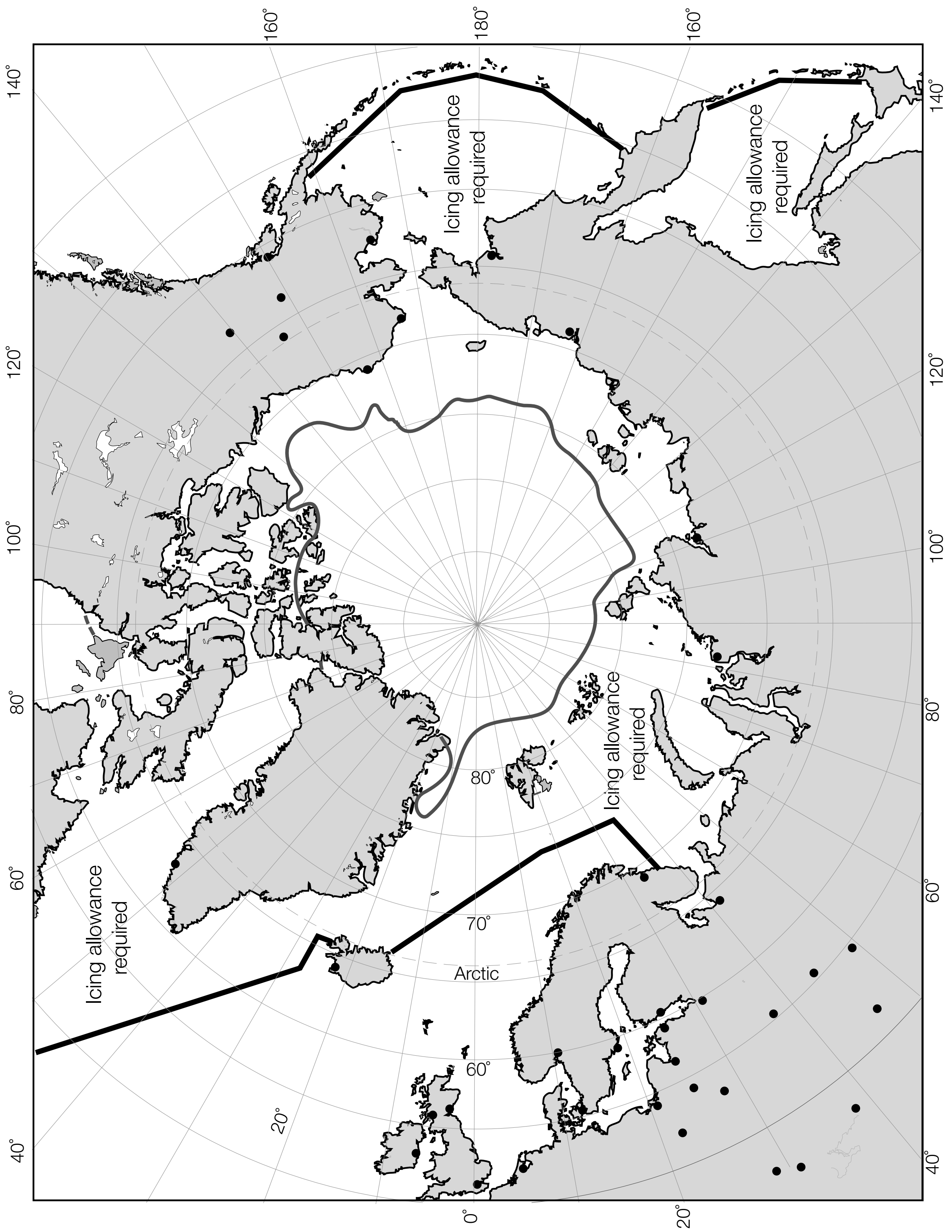


Fig. 2.4.2(a) Ice accretion limits Arctic

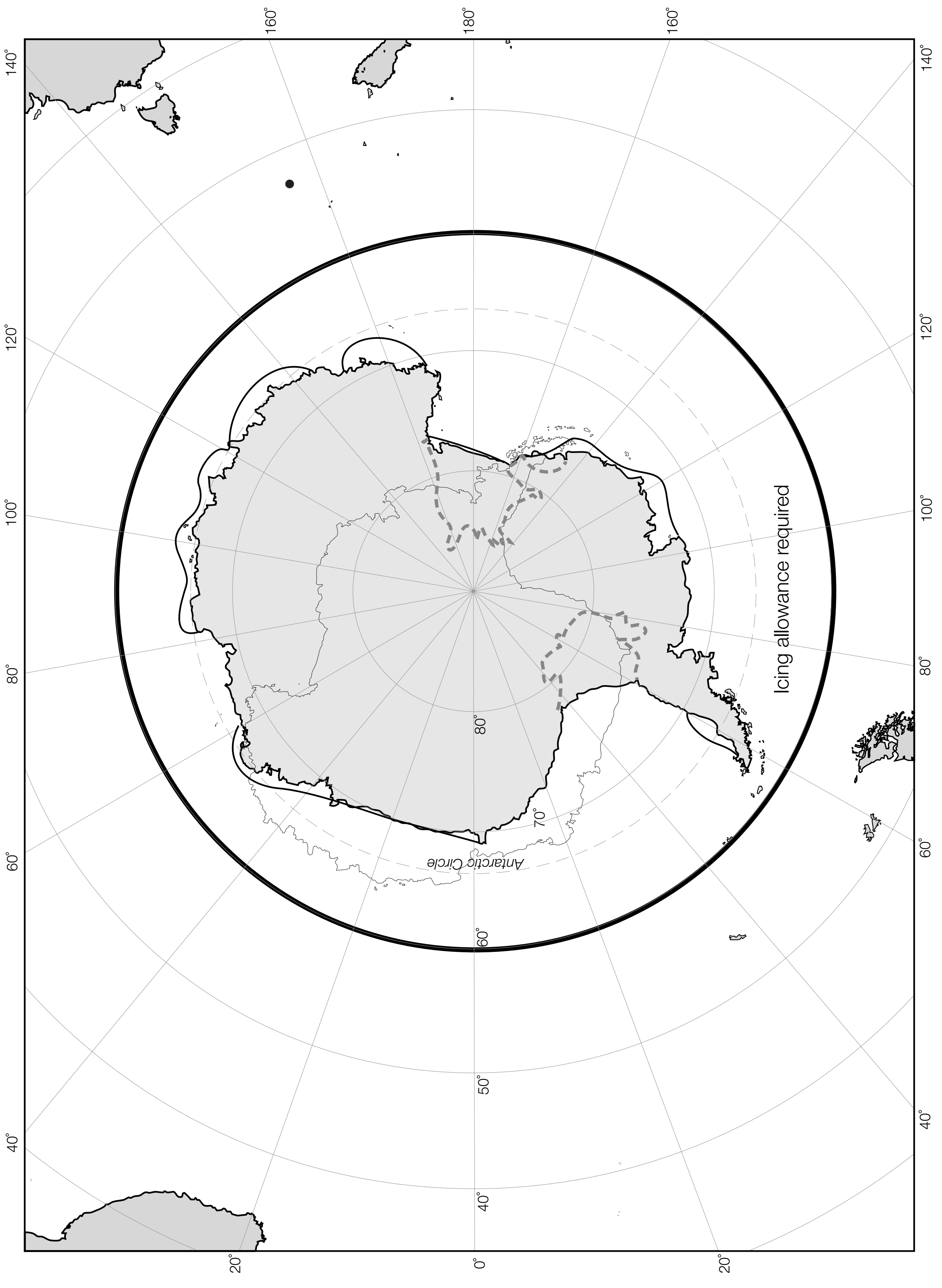


Fig. 2.4.2(b) Ice accretion limits Antarctica

Section

■ *Section 1* Introduction

1.1 General

1.1.1 This Chapter contains information regarding the derivation of local design loads that are to be used for the assessment of scantlings to local loads as specified in Pt 6, Ch 2.

1.1.2 The formulae for ship motion loads given in this Chapter are suitable for all ships that operate in the displacement mode. Ship motion loads for ships that operate in the fully planing mode will need to be specially considered.

1.1.3 Fig. 3.1.1 gives an overview of the contents of this Chapter, the locations of the local load components and the route through the Chapter.

1.2 Environmental conditions

1.2.1 The environmental conditions for the determination of the local loads are to be based on the normal environmental design criteria specified in Pt 5, Ch 2,2.3 unless otherwise stated.

1.2.2 The wave height factor for local loads, f_{Hs}, is dependant on the service area notation and is to be taken as follows:

f_{Hs} = 1,0 for SA1 service area notation, i.e. unrestricted sea-going service

otherwise

$$f_{Hs} = \frac{\text{design wave height for the restricted service}}{\text{design wave for unrestricted service}}$$

$$= \frac{H_{dw}}{H_{dw} \text{ for SA1}}$$

f_{Hs} is not to be taken as less than 0,5
H_{dw} is given in Ch 2,2.3.3.

1.2.3 All other environmental parameters are defined in Chapter 2.

1.2.4 The local design loads for assessment of the residual strength notation, **RSA**, or for special loading conditions where the ship will not experience severe weather or severe seastates may be adjusted for the appropriate environmental conditions. A reduced wave height factor, f_{Hs}, may be applied, *see* 5.10 and Vol 1, Pt 5, Ch 3,5.10.3.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.
L_{WL}, B, B_{WL}, D, T and C_b are defined in Pt 3, Ch 1,5.2

f_{Hs} = wave height factor for service area, *see* 1.2.2

V_{cr} = two thirds the cruising speed, in knots

V_{sp} is to be taken as the greater of the cruising speed or two thirds the sprint speed, in knots. For ships where it is not required to maintain high speeds in severe weather then the value of V_{sp} may be specially considered

T = mean draught at midships to the design waterline, based on L_{WL}, measured from the baseline

T_x = local draught to design waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing though the bottom of the moulded hull at midships, *see* Fig. 3.1.2

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

y = transverse distance, in metres, from the centreline to the centre of gravity of the item being considered. y is positive to port and negative to starboard

z = vertical distance, in metres, from the base line to the position or centre of gravity of the item being considered. z is positive above the baseline
Normally the following definitions are to be applied:
For a longitudinally framed plate panel, z is to be taken at the panel centre
For a transversely framed plate panel, z is to be taken at two thirds of the panel height
For short stiffener members: z is to be taken at the stiffener mid position
For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see* Fig. 3.1.2

Δ = moulded displacement of the ship, in tonnes.

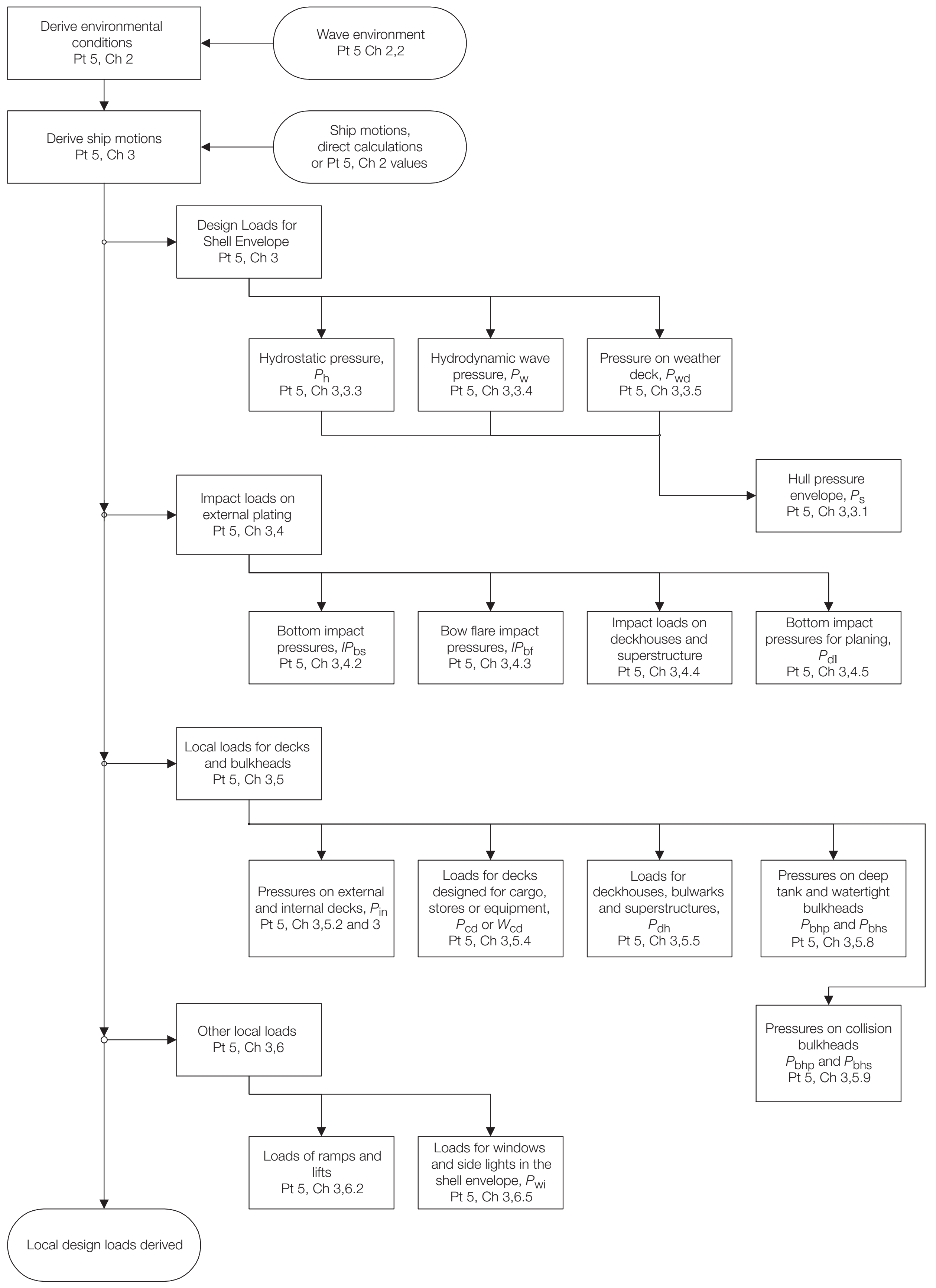


Fig. 3.1.1 Overview of derivation of local design loads

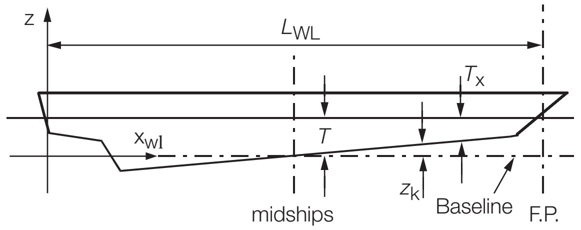


Fig. 3.1.2 Definition of draft *T* and baseline

1.3.2 **Froude Number F_n**. The Froude number is a non-dimensional parameter which is the primary constituent part of the wave making resistance and which dictates the maximum displacement speed. It is defined as:

$$F_n = \frac{V_m}{\sqrt{g\,L_{WL}}}$$

where

g is the acceleration due to gravity and is taken to be 9,81 m/s^2

L_{WL} is defined in 1.3.1

V_m is the appropriate ship speed in m/s.

1.3.3 **Design loading condition**. The design loading condition is to be taken as the normal operating deep draft condition with tanks and consumables, etc in the departure state. Where there is a significant variation in loading conditions or operating modes, then it may be necessary to consider additional loading conditions which represent the extremes of service requirements. For example:

- a ship which can operate in displacement and non-displacement modes;
- a ship which is required to operate at a much deeper draft than the normal seagoing draft for off-loading payload.
- a ship which is required to be involved in humanitarian emergency evacuation incidents or similar situations where short term overloading may be necessary.

1.3.4 **LCG**. The LCG is the longitudinal centre of gravity of the ship measured in metres from the aft end of the L_{WL} for the design loading condition.

1.3.5 **Displacement mode**. Displacement mode means the regime, whether at rest or in motion, where the weight of the ship is fully or predominantly supported by hydrostatic forces.

1.3.6 **Fully planing mode or Non-displacement mode**. Non-displacement mode means the normal operational regime of a ship when non-hydrostatic forces substantially or predominantly support the weight of the ship.

■ *Section 2* **Motion response**

2.1 General

2.1.1 The motions of the ship are to be considered in deriving the dynamic loads acting on the ship. The formulae given in this section may be utilised or ship motion design values may be derived by direct calculation methods or model testing.

2.1.2 For the assessment of mass inertial forces acting on structure the following combinations of static and dynamic forces are to be considered:

(a) Rolling motion only:
Static roll + dynamic roll + dynamic heave (at roll angle)

(b) Pitching motion only:
Static pitch + dynamic pitch + dynamic heave (at pitch angle)

(c) Combined motion:
Static combined +0,8 (dynamic roll + dynamic pitch)

Full details of the load cases applied are to be submitted for approval.

2.2 Ship motions

2.2.1 The ship motion response data given in Table 3.2.1 are to be used in the design calculations. Alternatively, the ship motion responses may be derived by direct calculation or equivalent methods.

2.3 Design accelerations

2.3.1 The non-dimensional ship motion acceleration values given in this section are to be used in the design calculations. The equations given here are applicable to ships with conventional hull forms operating in the displacement mode at their normal ship service speed or cruising speed. It is not normally necessary to consider the ship motion or acceleration values at sprint speeds unless there is a particular requirement to operate at sprint speeds in severe seastates.

2.3.2 The following formulae are given as guidance for the components of acceleration due to ship motions and apply for ships with a length exceeding 50 m and the speed is such that the ship is operating within the displacement mode based on normal ship service speed. Typically this will apply to most ships with displacement hull forms that are not designed to operate in the planing regime.

Vertical acceleration due to heave, pitch and roll motions

$$a_z = \pm\sqrt{(a_{heave}{}^2 + a_{pitch}{}^2 + a_{rollz}{}^2)}$$

Transverse acceleration due to sway, yaw and roll motions

$$a_y = \pm\sqrt{(a_{sway}{}^2 + a_{yaw}{}^2 + a_{rolly}{}^2)}$$

Longitudinal acceleration due to surge motions

$$a_x = \pm\, a_o\sqrt{(0{,}06 + A^2 - 0{,}25A)}$$

where

Table 3.2.1 Ship motions

Motion			Acceleration
Heave		a_{heave}	$= a_o$
Pitch		a_{pitch}	$= a_o \left(5{,}3 - \dfrac{45}{L_{WL}}\right)\left(\dfrac{x_{wl} - L_{CG}}{L_{WL}}\right)\left(\dfrac{0{,}6}{C_b}\right)^{0{,}75}$
Sway		a_{sway}	$= a_o\ 0{,}78$
Yaw		a_{yaw}	$= a_o\ 1{,}6 \left(\dfrac{x_{wl} - L_{CG}}{L_{WL}}\right)$
Roll	Acceleration due to Roll Vertical direction	a_{rollz}	$= a_o \dfrac{0{,}6y\,K^{1{,}5}}{B_{WL}}$
Roll	Acceleration due to Roll Transverse direction	a_{rolly}	$= a_o \sqrt{K}\left(1 + 0{,}6K\left(\dfrac{z - T}{B_{WL}}\right)\right)$
		a_o	$= f_{Hs}\, f_{st} \left(\dfrac{0{,}2V}{\sqrt{L_{WL}}} + \dfrac{34 - \left(\dfrac{600}{L_{WL}}\right)}{L_{WL}}\right)$
Relative vertical motion		H_{rm}	$= C_{w,min}\left(1 + \dfrac{k_r}{(C_b + 0{,}2)}\left(\dfrac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$

Symbols

f_{st} = correction factor for long term (10^{-8}) acceleration value to average of the highest 1/100 acceleration values
= 0,8

C_w = a wave head, in metres
$= f_{Hs}\, 0{,}0771 L_{WL}\, (C_b + 0{,}2)^{0{,}3}\ e^{(-0{,}0044 L_{WL})}$

$C_{w,min} = \dfrac{C_w}{k_m}\sqrt{\dfrac{2{,}25}{k_r}}$

$k_m = 1 + \dfrac{k_r\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$

$x_m = 0{,}45 - 0{,}6F_n$ but x_m is not to be less than 0,2

k_r = 2,25 for the determination of pressure loads in Section 3

k_r = 4,5 for the determination of impact loads in Section 4

V is appropriate design speed as follows:

$V = V_{cr}$ for determination of pressure in Section 3, local design loads in Section 5 and 6, and all other loads unless specifically noted
$= V_{sp}$ for determination of impact loads in Section 4

$F_n = \dfrac{0{,}515V}{\sqrt{g\,L_{WL}}}$

K = 1 in general. For particular loading conditions and hull forms, determination of K according to the formula below may be necessary

K = 13 GM/B_{WL}, but ≥ 1,0

GM = metacentric height, in metres

f_{Hs} and B_{WL} are defined in 1.3.1

L_{CG} is defined in 1.3.4

NOTES
1. Heave motion is measured positive upwards.
2. Pitch motion is measured positive bow downwards.
3. Sway motion is measure positive to port.
4. Yaw motion is measured positive bow to port.
5. Roll motion is measured positive port side upwards.

$$A = f_{Hs}\, f_{st} \left(0{,}7 - \frac{L_{WL}}{1200} + \frac{5\,(z - T)}{L_{WL}}\right)\left(\frac{0{,}6}{C_b}\right)$$

and

a_x, a_y and a_z are the maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions and are considered as acting separately for calculation purposes

a_x measured positive in the forward direction

a_y measured positive in the transverse direction to port

a_z measured positive in the downwards direction, i.e. adds to g

NOTES:

a_x includes the component due to static weight in the longitudinal direction due to pitching

a_y includes the component due to static weight in the transverse direction due to rolling

a_z does not include the component due to static weight

a_o, a_{heave}, a_{pitch}, a_{rollz}, a_{sway}, a_{yaw}, a_{rolly} and A are defined in Table 3.2.1

f_{st} is defined in Table 3.2.1

f_{Hs} is defined in 1.2.2

T, L_{WL}, C_b and z are defined in 1.3.1.

2.4 Design vertical acceleration for ships in the planing regime

2.4.1 The design vertical acceleration for the derivation of bottom impact pressures for ships operating in the planing regime may be derived using the following sections.

2.4.2 The non-dimensional vertical acceleration at the LCG, a_{op}, is defined as the average of the 1/100 highest accelerations and is to be taken as:

$$a_{op} = 5{,}66g\ \theta_B\ L_1\ (H_1 + 0{,}084)\ (5 - 0{,}1\theta_D)\ F_n^2\ 10^{-3}$$

where

F_n = Froude number based on V_{sp}, where V_{sp} is defined in 1.3.1, F_n is defined in 1.3.2

g = acceleration due to gravity (9,81 m/sec^2)

$L_1 = \dfrac{L_{WL}\ B_c^3}{B_{WL}\ \Delta}$, but $\dfrac{L_{WL}}{B_{WL}}$ is not to be taken as less than 3

$H_1 = \dfrac{H_{dw}}{B_{WL}}$ but not less than 0,2

B_c = breadth of hull between the chines or bilge tangential points at the LCG, as appropriate, in metres, *see* Fig. 3.2.1

H_{dw} = design wave height in metres, *see* Ch 2,2.3.3

θ_D = deadrise angle at the LCG, in degrees, but is not taken as greater 30°, *see* Fig. 3.2.1.

θ_B = running trim angle in degrees, but is not to be taken as less than 3°

B_{WL}, Δ, L_{WL} are defined in 1.3.1

LCG is defined in 1.3.4

NOTES:

- The bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see* Fig. 3.2.1.
- For ships with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see* Fig. 3.2.1.
- For ships with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used.

2.4.3 Where the Froude number, F_n, is greater than 1,8, the motion response criteria are to be specially considered.

2.4.4 The vertical non dimensional acceleration, a_z, at any given distance x along the hull may be taken as:

$$a_z = a_{op}\left(1{,}0 - 0{,}32\,\frac{(x_{wl} - L_{CG})}{L_{WL}} + 1{,}76\left(\frac{x_{wl}^2 - L_{CG}^2}{L_{WL}^2}\right)\right)$$

where

a_z = is the vertical acceleration in terms of g

x_{wl} = distance from aft end of L_{WL}, in metres, to the point at which the vertical acceleration is calculated

L_{CG} is defined in 1.3.4.

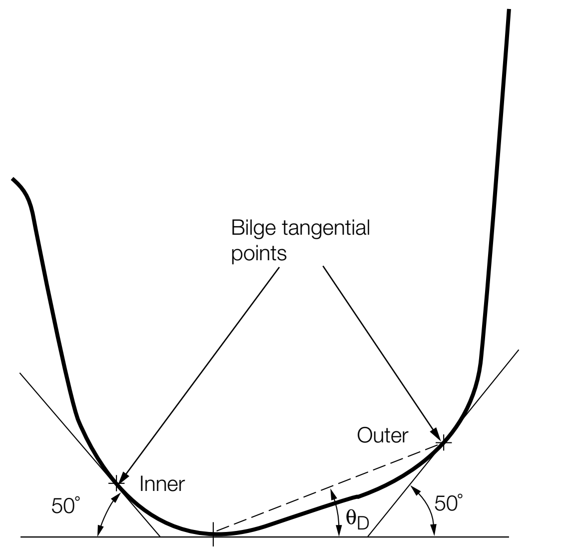


Fig. 3.2.1 Definition of bilge tangential point

■ *Section 3* Loads on shell envelope

3.1 Pressures on the shell envelope

3.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition the effects of impact or slamming loads are also to be considered, but these may be treated separately, *see* Section 4.

3.1.2 The individual pressure components are given in 3.3 to 3.5 and the combined pressure to be applied to the shell envelope is given in 3.2. The pressure to be applied to exposed and weather decks is given in 3.5.

3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, P_s

3.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in Fig. 3.3.1 and is to be taken as specified in Table 3.3.1.

3.3 Hydrostatic pressure on the shell plating, P_h

3.3.1 The pressure, P_h, acting on the shell plating up to the design waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\ (T_x - (z - z_k))\ \text{kN/m}^2$$

where

T_x, z and z_k are defined in 1.3.

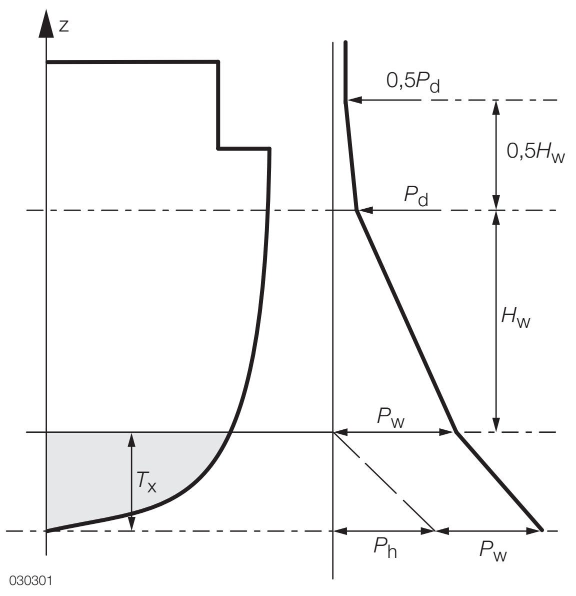


Fig. 3.3.1 Combined pressure distribution, P_s

Table 3.3.1

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
for $z \le T_x + z_k P_h + P_w$ i.e. up to the design waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
P_h is the hydrostatic pressure, *see* 3.3 P_w is the hydrodynamic wave pressure, *see* 3.4 P_d is the weather deck pressure, *see* 3.5.2 H_w is the nominal wave limit height, *see* 3.4.4 P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in 1.3	
NOTE Pressure values at other z values are to be derived by interpolation.	

3.4 Hydrodynamic wave pressure, P_w

3.4.1 The hydrodynamic wave pressure distribution, P_w, around the shell envelope up to the design waterline, i.e. $z \le T_x$, is to be taken as the greater of the following:

P_m kN/m^2 (relative motion)

P_p kN/m^2 (pitching motion)

where

P_m and P_p are defined in 3.4.2 and 3.4.3.

3.4.2 The distribution of hydrodynamic pressure up to the design waterline, P_m, due to relative motion is to be taken as:

$$P_m = 10\, f_z\, H_{rm} \text{ kN/m}^2$$

where

f_z = the vertical distribution factor

$$= k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$$

$$k_z = e^{-u}$$

$$u = \left(\frac{2\pi\, T_x}{L_{WL}}\right)$$

$H_{r\,m}$ is defined in Table 3.2.1

z, z_k, T_x and L_{WL} are defined in 1.3.

3.4.3 The distribution of hydrodynamic pressure up to the design waterline due to pitching motion, P_p, is to be taken as:

$$P_p = 10\, H_{pm} \text{ kN/m}^2$$

where

$$H_{pm} = 1{,}1 f_{Hs}\left(\frac{2x_{wl}}{L_{WL}} - 1\right)\sqrt{L_p}$$

but not less than $0{,}3f_{Hs}$

where

$L_P = L_{WL}$ but $\le$ 150 m

x_{wl}, L_{WL} and f_{Hs} are defined in 1.3.

3.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2\, H_{rm} \text{ m}$$

where

$H_{r\,m}$ is given in Table 3.2.1.

3.5 Pressure on exposed and weather decks, P_{wd}

3.5.1 The pressure acting on weather decks, exposed decks or decks designed for prolonged immersion, P_{wd}, is illustrated in Fig. 3.3.2 and is to be taken as specified in Table 3.3.2.

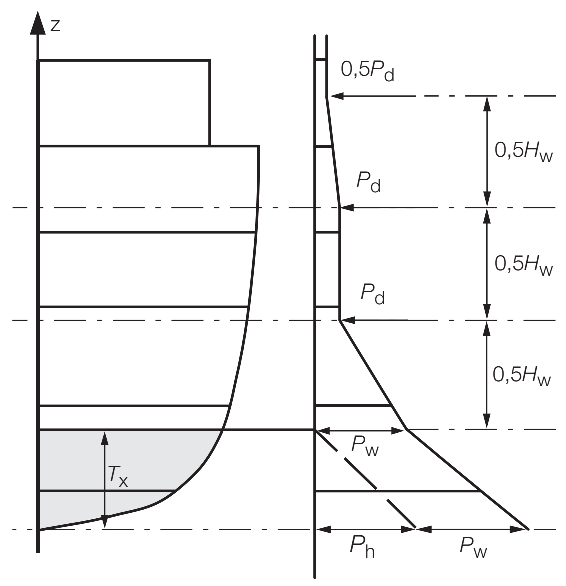


Fig. 3.3.2 Weather deck pressure distribution, P_{wd}

Table 3.3.2

Vertical location i.e. z value	Exposed/weather deck pressure, P_{wd} kN/m^2
for $z \le T_x + z_k$ i.e. up to the design waterline	$P_h + P_w$
At $z = T_x + z_k + 0{,}5H_w$	P_d
At $z = T_x + z_k + 1{,}0H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
P_h is the hydrostatic pressure, *see* 3.3 P_w is the hydrodynamic wave pressure, *see* 3.4 P_d is the weather deck pressure, *see* 3.5.2 H_w is the nominal wave limit height, *see* 3.4.4 P_h and P_w are all taken at the appropriate vertical position, z T_x, z and z_k are defined in 1.3	
NOTE Pressure values at other z values are to be derived by interpolation.	

3.5.2 The minimum design pressure for weather decks, P_d, above the $0{,}5H_w$ limit line and below the $1{,}0H_w$ limit line is to be taken as:

$P_d = 6 + 6f_L\, f_{Hs}$ kN/m^2

where

f_L = a location factor

$= 1 + 4\left(\dfrac{x_{wl}}{L_{WL}} - 0{,}75\right)$

but not less than 1,0

L_{WL} and x_{wl} are defined in 1.3

f_{Hs} is defined in 1.2.

3.5.3 If a bulwark is fitted at the deck edge then consideration will be given to allowing the height of the top of the bulwark to be used for the pressure calculation.

■ *Section 4* Impact loads on external plating

4.1 General

4.1.1 The effects of impact or slamming loads on the shell envelope are to be considered. This section gives formulations for equivalent design pressure loads. Alternatively the impact pressure loads may be derived using suitable direct calculation methods.

4.1.2 The methods below produce average instantaneous impact pressures which need to be converted to equivalent static pressures by application of a dynamic load factor, *see* Pt 6, Ch 2,6 and Pt 6, Ch 3, Sections 14 and 15.

4.1.3 These methods are based on the Ochi-Motter slamming approach and are equivalent to the standard direct calculation procedure. The values of m_0, variance of the relative vertical motion, and m_1, variance of the relative vertical velocity, may be derived using direct calculations. In this case the variances are to be based on seastates as defined by the normal design assessment environmental criteria, *see* Ch 2,2.3.

4.2 Bottom impact pressure, IP_{bi}

4.2.1 The bottom impact pressure due to slamming, IP_{bi}, is to be derived using the method given below. This method will produce impact pressures over the whole of the underwater plating region:

$IP_{bi} = 0{,}5k_{s1}\, V_{bs}^2$ kN/m^2

where

k_{s1} = hull form shape coefficient

$= \dfrac{\pi}{\operatorname{Tan}\beta_p}$ for $\beta_p \ge 10$

$= 28\,(1 - \operatorname{Tan}(2\beta_p))$ for $\beta_p < 10$

β_p = deadrise angle,in degrees, *see* Fig. 3.4.1

V_{bs} = slamming velocity, in m/s, and is given by

$= \sqrt{V_{th}^2 + 2m_1 \ln(N_{sl})}$ for $N_{sl} \ge 1$

$= 0$ for $N_{sl} < 1$

V_{th} = threshold velocity for slamming, in m/s, to be taken as:

$= \sqrt{10}$

N_{sl} = No of slams in a 3 hour period and is given by

$= 1720PR_{sl}\sqrt{\dfrac{m_1}{m_0}}$

PR_{sl} = probability of a slam and is given by

$= e^{-u}$

$u = \left(\dfrac{z_{wl}^2}{2m_0} + \dfrac{V_{th}^2}{2m_1}\right)$

z_{wl} = distance of the centroid of the area of plating or stiffener to the local design waterline

$= z - (T_x + z_k)$

m_1 = variance of the relative vertical velocity

$= 0{,}25\,(\omega_e\, f_{s1}\, H_{r\,m})^2$

m_0 = variance of the relative vertical motion

$= 0{,}25\,(f_{s1}\, H_{r\,m})^2$

ω = effective wave frequency based on 80 per cent ship length

$= \sqrt{\dfrac{2\pi g}{0{,}8L_{WL}}}$

ω_e = effective encounter wave frequency

$= \omega\left(1 + \dfrac{0{,}2\omega\, V_{sp}}{g}\right)$

$H_{r\,m}$ = relative vertical motion based on V_{sp}, *see* Table 3.2.1

f_{s1} = probability level correction factor for relative vertical motion

$= 1{,}0$ for ships with $C_b \le 0{,}6$

$= 1{,}2$ for ships with $C_b > 0{,}6$

C_b = block coefficient as defied in Pt 3, Ch 1,5

V_{sp}, z, z_k and T_x are defined in 1.3

See Fig. 3.4.1

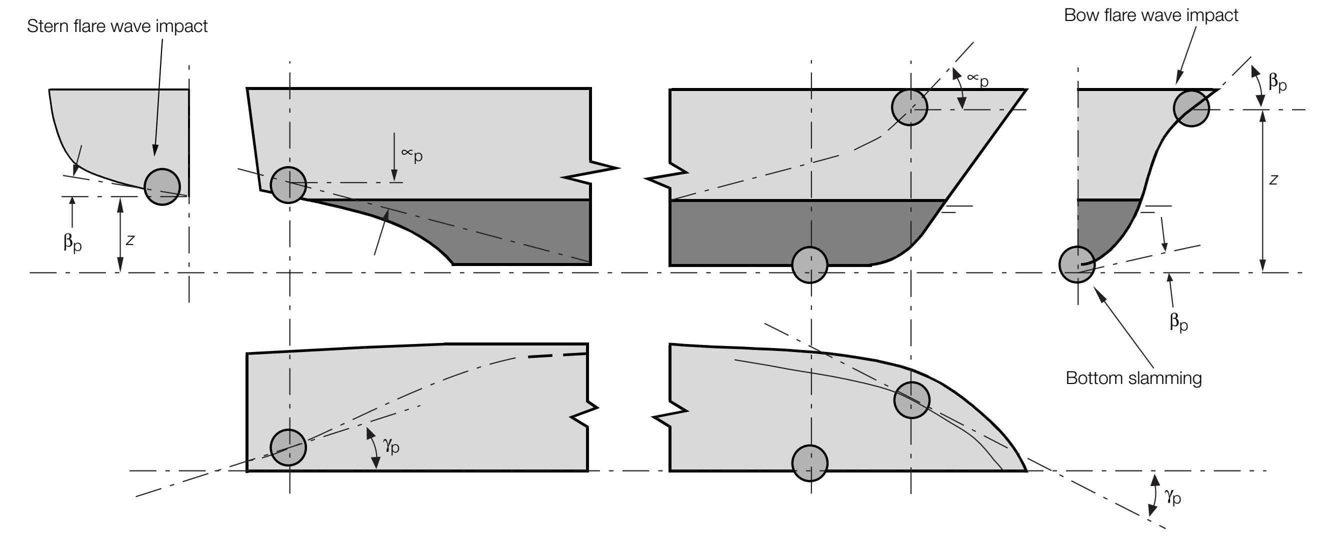


Fig. 3.4.1 Bow flare and bottom slamming angles

4.2.2 For the purposes of deriving the dynamic load factor, the rise time of the impact pressure may be taken as:

$$t_r = \frac{1}{4\sqrt{IP_{bi}}} \text{ seconds}$$

It is assumed that the impact pressure may be represented by a triangular pulse load.

4.3 Bow flare and above waterline wave impact pressures, IP_{bf}

4.3.1 The bow flare wave impact pressure, wave impact pressure on sponsons and other parts of the side shell plating above the design waterline, IP_{bf}, in kN/m^2, due to relative motion is to be taken as:

$$IP_{bf} = 0{,}5\,(k_{bf}\,V_{bf}^2 + k_{rv}\,H_{rv}\,V_{rv}^2) \quad \text{kN/m}^2$$

where

k_{bf} = hull form shape coefficient for wave impacts

$= \dfrac{\pi}{\operatorname{Tan}\beta_p}$ for $\beta_p \geq 10$

$= 28\,(1 - \operatorname{Tan}(2\beta_p))$ for $\beta_p < 10$

V_{bf} wave impact velocity, in m/s, and is given by

$= \sqrt{V_{thbf}^2 + 2m_1 \ln (N_{bf})}$ for $N_{bf} \geq 1$

$= 0$ for $N_{bf} < 1$

V_{thbf} = threshold velocity for wave impact, in m/s, to be taken as:

$= \dfrac{\sqrt{10}}{\cos\alpha_p}$

N_{bf} = No of wave impacts in a 3 hour period and is given by

$= 1720 PR_{bf} \sqrt{\dfrac{m_1}{m_0}}$

PR_{bf} = probability of a wave impact and is given by

$= e^{-u}$

$u = \left(\dfrac{z_{wl}^2}{2m_0} + \dfrac{V_{thbf}^2}{2m_1}\right)$

z_{wl}, m_1, m_0 are defined in 4.2 and

k_{rv} = hull form shape coefficient for impact due to forward speed

$= \dfrac{\pi}{\operatorname{Tan}(90 - \alpha_p)}$ for $\alpha_p \leq 80$

$= 28\,(1 - \tan(2\,(90 - \alpha_p)))$ for $\alpha_p > 80$

H_{rv} = relative wave heading coefficient

$= 1{,}0$ for $\gamma_p \geq 45$

$= \cos(45 - \gamma_p)$ for $\gamma_p < 45$ and ≥ 0

$= 0$ for $\gamma_p < 0$

V_{rv} = relative forward speed, in m/s

$= 0{,}515\, V_{sp} \sin(\gamma_p)$

α_p = buttock angle, in degrees, *see* Fig. 3.4.1

β_p = deadrise angle, in degrees, *see* Fig. 3.4.1. Note the deadrise angle is to be decreased by 10° to allow for the effects of roll motion on the above waterline impact pressures for ships with $C_b \leq 0{,}6$

γ_p = waterline angle, in degrees, *see* Fig. 3.4.1

C_b = Block coefficient as defined in Pt 3, Ch 1,5

NOTES

Where only two angles are known, then the third may be obtained by the following expression:

$\alpha = \operatorname{Tan}^{-1}(\operatorname{Tan}\beta \operatorname{Tan}\gamma)$

If the area of plating under consideration has a waterline angle which is re-entrant or decreasing, e.g. in the stern region, then the relative wave heading coefficient, H_{rv}, and the speed V_{sp}, used in the derivation of $H_{r\,m}$, are to be taken as zero. V_{sp} is defined in 1.3.1.

4.3.2 For the purposes of deriving the dynamic load factor, the rise time of the wave impact pressure may be taken as:

$$t_r = \frac{1}{4\sqrt{IP_{bf}}} \text{ seconds}$$

It is assumed that the wave impact pressure may be represented by a triangular pulse load.

4.3.3 The extents around the girth of the bow flare wave impact pressure are to be derived as follows:

(a) the vertical slam extent, g_{bfv}, is to be taken as:

$$g_{bfv} = \frac{4}{\sin\beta_p \sqrt{8k_{bf}}} \text{ m}$$

(b) the horizontal slam extent, g_{bfh}, is to be taken as:

$$g_{bfh} = 4 \text{ m}$$

where

k_{bf} and β_p are given in 4.3.1.

4.4 Impact loads on deckhouses and superstructures

4.4.1 Normally, it may be assumed that the equivalent static pressure loads given in 5.5 make due allowance for impact loads on deckhouse fronts and sides.

4.5 Bottom impact pressure for ships operating in the planing regime

4.5.1 The equivalent static bottom impact pressure due to slamming, P_{dI}, at the LCG for mono-hull planing hull forms is given by the following expression:

$$P_{dI} = \frac{k_{dI}\,\Delta\, f_{dI}\,(1 + a_{op})}{L_{WL}\, G_o} \quad \text{kN/m}^2$$

where

G_o = support girth or girth distance, in metres, as defined in Table 3.4.1

L_{WL} = waterline length, in metres, *see* 1.3.1

a_{op} = vertical acceleration as defined in 2.4

k_{dI} = hull form pressure factor
= 54

For craft in continuous contact with water:

f_{dI} = 0,5 for $x = 0{,}0L_{WL}$
= 1,0 for $x = 0{,}5L_{WL}$
= 1,0 for $x = 0{,}75L_{WL}$
= 0,5 for $x = 1{,}0L_{WL}$

Intermediate values to be determined by linear interpolation. Otherwise f_{dI} = 1,0.

Table 3.4.1 Definition of G_o for the determination of bottom impact pressure, P_{dI}, for different regions

Bottom shell region	G_o	
	Hull forms with chines	Hull forms without chines
Between tangential points or chines	G_s	G_s
Between tangential points and design waterline	—	G_{WL}

NOTES
1. G_s = support girth, in metres. This is the girth distance measured between the bilge tangential points or chines at the LCG. The bilge tangential point is defined as the point where a line 50° above the horizontal touches the bilge plating, *see* Fig. 3.2.1.
2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.

■ *Section 5* Local design loads for decks and bulkheads

5.1 General

5.1.1 This section gives formulations for design pressure loads for decks, watertight and deep tank boundaries including decks and bulkheads.

5.1.2 The loads acting on the deck structures are to reflect the intended purpose for each deck. If it is envisaged that the role of the ship will be such that it may be used for emergency evacuation incidents or similar situations, then the appropriate design loads are to be considered in the assessment. The maximum permissible deck loading are to be recorded in the Operations Manual or Stability Information Book.

5.1.3 Bulkheads and decks forming the boundary of tanks are to be assessed in accordance with the requirements for deep tanks using the loads defined in 5.8 and 5.9 or the maximum load experienced in service, e.g. from RAS operations, whichever is the greater. For an open system the pressure height may be taken from the keel to the filling point open to the atmosphere.

5.1.4 Loads on decks and bulkheads due to magazine over pressure and magazine flooding are to be considered as defined by the Naval Authority, *see* Pt 4, Ch 1,6.4.

5.2 Pressure on external decks

5.2.1 The standard pressure requirements for external decks are given in 3.5. If the deck is also to be used for cargo, heavy equipment or similar, then the loads specified in 5.4 are also to be applied. Consideration will be given to a reduction in the weather deck pressure loading if it can be shown that the cargo or equipment stowage makes the weather deck pressure requirements conservative.

5.3 Pressure on internal decks, P_{in}

5.3.1 The pressure acting on internal decks, P_{in}, not subject to cargo or heavy equipment loads is to be taken as:

P_{in} = 5 kN/m^2 for accommodation spaces
P_{in} = 10 kN/m^2 for workshop spaces
P_{in} = 20 kN/m^2 for store spaces.

5.3.2 Alternatively the design pressure is to be based on the static loading on the deck with due allowance for inertial effects as follows:

$$P_{in} = W_{in}\,(1 + a_z) \;\; \text{kN/m}^2$$

where the following values of static pressure are to be assumed

W_{in} = 3 kN/m^2 for accommodation spaces
W_{in} = 6 kN/m^2 for workshop spaces
W_{in} = 12 kN/m^2 for store spaces
a_z is defined in 2.3.2.

5.3.3 The hydrostatic design pressure for decks specified as watertight by the Naval Authority shall be taken as that determined by the damage stability analysis and limit of water-tight integrity.

5.3.4 The static design pressure for internal decks not specified as watertight may be provided by the designer.

5.4 Loads for decks designed for cargo or heavy equipment loads, P_{cd} and W_{cd}

5.4.1 Where the load applied to the deck can be considered as uniformly distributed, the cargo deck design pressure, P_{cd}, is to be taken as:

$$P_{cd} = W_{cd}\,(1 + a_z) \;\; \text{kN/m}^2$$

where

a_z is the non dimensional vertical acceleration given in 2.3.2.
W_{cd} is the static pressure exerted by the cargo on the deck as specified by the designer in kN/m^2.

5.4.2 Where the load applied to the deck is not uniformly distributed, the likely actual forces and force distribution over the deck must be considered. The forces are to include the following if appropriate:

- gravity
- inertial forces due to ship motion
- wind loads
- forces imposed by the securing arrangements
- wave impact loads
- icing loads

$$F_{cd} = W_{ma}\,(1 + a_z) \;\; \text{kN}$$

where
W_{ma} is the weight of each mass item on the deck as specified by the designer in kN.

5.5 Loads for deckhouses, bulwarks and superstructures, P_{dh}

5.5.1 The design normal pressure, P_{dh}, for the side, front and back panels of plating and stiffeners for deckhouses, bulwarks and superstructures is given by:

$$P_{dh} = C_1\, P_s \;\; \text{kN/m}^2$$

where

C_1 = 1,25C_2 for exposed deckhouse fronts and superstructure fronts forward of 0,67L_R
= 1,15C_2 for exposed deckhouse fronts and superstructure fronts aft of 0,67L_R
= 1,15 for exposed machinery casings
= 0,8 for the side and back panels of deckhouses that are stepped in from the deck edge by 1,0 m or more which are also above the nominal wave limit height, H_w, *see* 3.4.4
= 0,5 for non-exposed deckhouse and super structure fronts, sides and backs which are also above the nominal wave limit height
= 1,0 elsewhere

P_s is to be taken at the height of the deck supporting the deckhouse front, side or back panel under consideration, P_s is defined in 3.2

C_2 = 1,2 for panels below the nominal wave limit height
= 1,0 elsewhere

Typical values of C_1 are shown in Fig. 3.5.1

Where there is more than one deckhouse, the front of the most forward deckhouse will normally be considered exposed, whereas the back of this deckhouse will be non-exposed. Normally, the front of the deckhouse aft of this one will also be considered non-exposed.

5.6 Pressure height for deep tank bulkheads and boundaries, H_{tk}

5.6.1 The design lateral pressure height for tank and deep tank bulkheads and boundaries, H_{tk}, is to be taken as

H_{tk} = the distance, in m, from the baseline to half the distance from the top of the tank to the top of the overflow. For determination of the maximum head, the top of the overflow is to be taken as not less than 1,8 m above the crown of the tank, *see* Fig. 3.5.2.

5.6.2 For tanks which are connected to a filling tank system, H_{tk} may be taken as the distance, in m, from the baseline to the highest point of the overflow pipe from the filling tank into the overflow tank. Consideration may need to be given to the pressure height for situations where any of the valves in the filling system may be closed. The transfer pump must feed only into the filling tank and must not be linked directly to tanks.

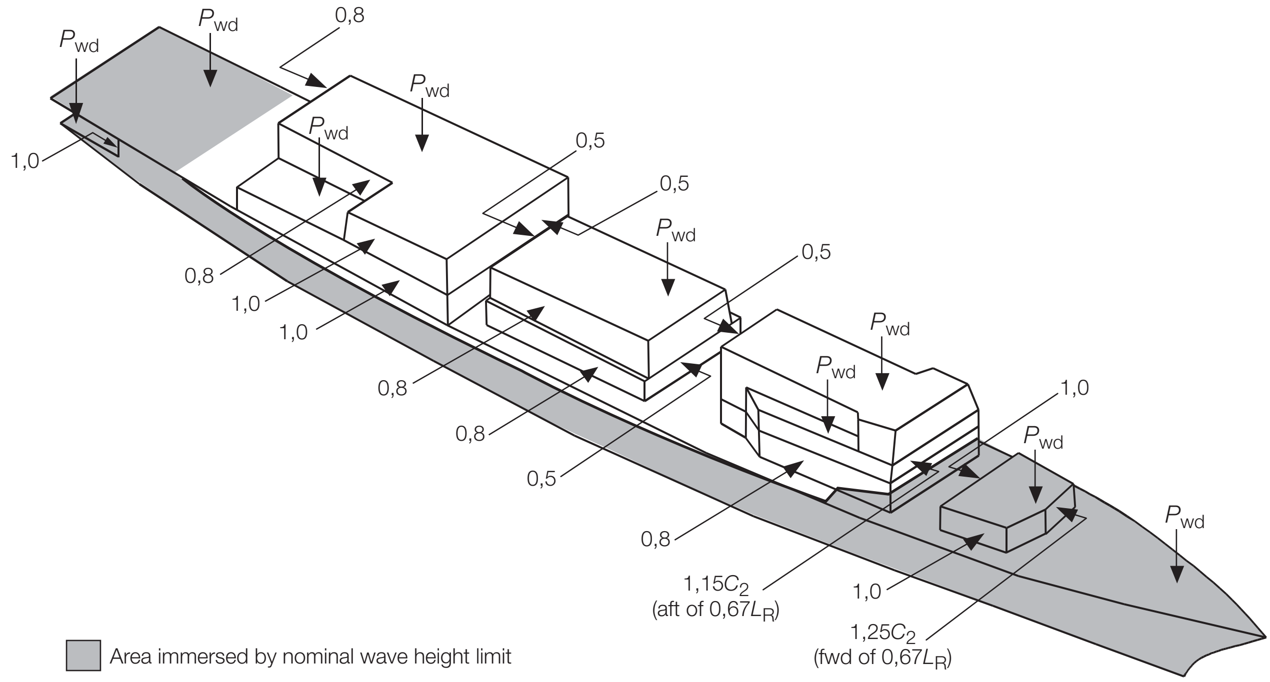


Fig. 3.5.1 Illustration of the C_1 coefficients for deckhouse and superstructure pressures

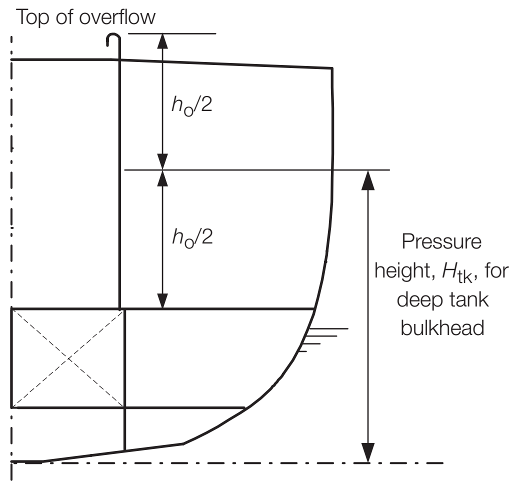


Fig. 3.5.2
Pressure height for deep tank bulkheads

5.6.3 In a filling tank system, suitable measures are to be provided such that the maximum design level in the system cannot be exceeded. Automatic shutdown measures are to ensure a fail safe arrangement to avoid overfilling the filling tank or the overflow tank. The overflow pipe is to be of sufficient size to ensure that the filling trunk is not overfilled.

5.7 Pressure height for watertight bulkheads and boundaries, H_{da}

5.7.1 The design lateral pressure height for watertight bulkheads and boundaries, H_{da}, is to be taken as

(a) for a watertight bulkhead design philosophy based on a SOLAS type approach, i.e. to the top of a watertight bulkhead deck or freeboard deck, *see* Pt 3, Ch 2,1.3.3.2 and illustrated in Pt 3, Ch 2, Fig 2.1.1(b).
H_{da} = the vertical distance, in m, from baseline to a line 0,91 m above the top of the watertight bulkhead at side, *see* Fig 3.5.3(a).

(b) for a watertight bulkhead design philosophy based on a standard which requires a damaged stability draft and heel envelope approach, e.g. the red risk line approach, *see* Pt 3, Ch 2,1.3.3.3 and illustrated in Pt 3, Ch 2, Fig. 2.1.2(b).
H_{da} = the distance, in m, from baseline to the damaged stability draft envelope at the centreline, *see* Fig 3.5.3(b).

Note: The effect of lesser angles of heel in the damage situation may lead to an increase in the effective pressure height, especially in way of the forward end of the ship where it may be necessary to consider H_{da} based on a zero heel angle.

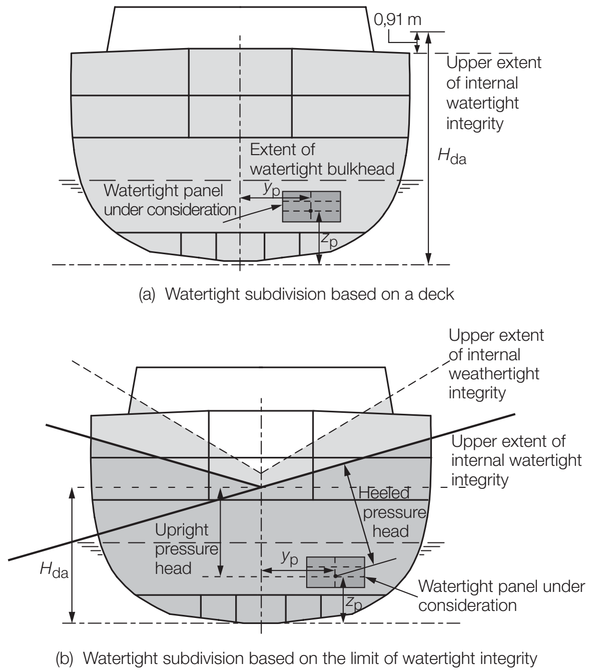


Fig. 3.5.3
Pressure height for watertight bulkheads

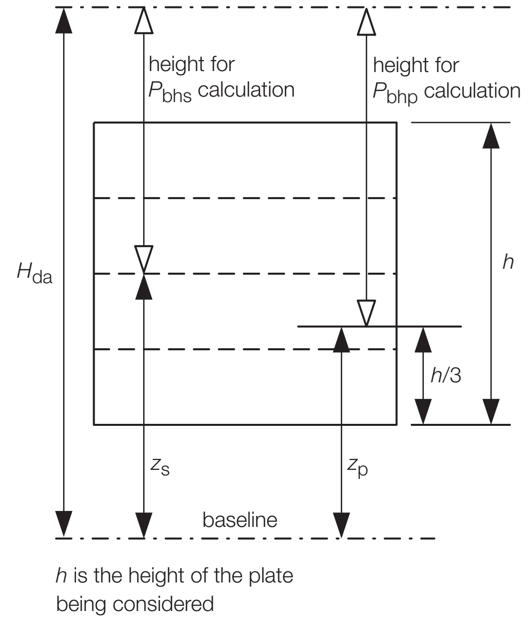


Fig. 3.5.4
***Z*, distance above baseline for pressure head for plating with horizontal stiffeners**

5.8 Design pressures for watertight and deep tank bulkheads and boundaries

5.8.1 The design normal pressure for bulkhead plating with stiffeners is to be considered separately for the plating and the stiffeners. The design normal pressure for the plating, P_{bhp}, is to be taken as follows:
Deep Tank

$\rho g\ (H_{tk} - z_p)$ kN/m^2

WT sub-division based on the head normal to the line of watertight integrity
maximum of

$10((H_{da} - z_p) \text{ Cos } \theta + y_p \text{ Sin } \theta))$ kN/m^2
$10(H_{da} - z_p)$ kN/m^2

where
ρ = density of fluid, in tonnes/m^3
z_p = distance above the baseline of a point one-third of the height, above the lower edge, of the plate strake under consideration. z_p is illustrated in Fig. 3.5.4 for horizontally stiffened plating and 3.5.5 for vertically stiffened plating
y_p = distance from the centreline to the mid-breadth of the plate strake under consideration. y_p is always to be taken as positive
θ = the stipulated damaged stability heel angle, *see also* Pt 3, Ch 2,1.3. For a SOLAS type approach, θ is normally to be taken as 0,0.

5.8.2 The design normal pressure for the stiffener, P_{bhs}, is to be taken as follows:
Deep Tank

$\rho g\ (H_{tk} - z_s)$ kN/m^2 (Deep Tank)

WT sub-division
maximum of:
$10((H_{da} - z_s) \text{ Cos } \theta + y_s \text{ Sin } \theta))$ kN/m^2
$10(H_{da} - z_s)$ kN/m^2

where
z_s = distance above baseline of the mid span of the vertical stiffener under consideration, *see* Fig. 3.5.5.
or
z_s = distance above baseline of the mid span of the horizontal stiffener under consideration, *see* Fig. 3.5.4
y_s = distance from the centreline to the mid span of the stiffener under consideration. y_s is always to be taken as positive
ρ = density of fluid, in tonnes/m^3.

5.8.3 The appropriate design criteria are to be applied to the bulkhead plating and stiffeners, *see* Pt 6, Ch 5. It is not permissible to use watertight criteria for a deep tank design head.

5.8.4 The design impulse pressure, IP_{bh}, for the bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar. In this case it will be necessary to determine the sloshing loads using a suitable direct calculation procedure.

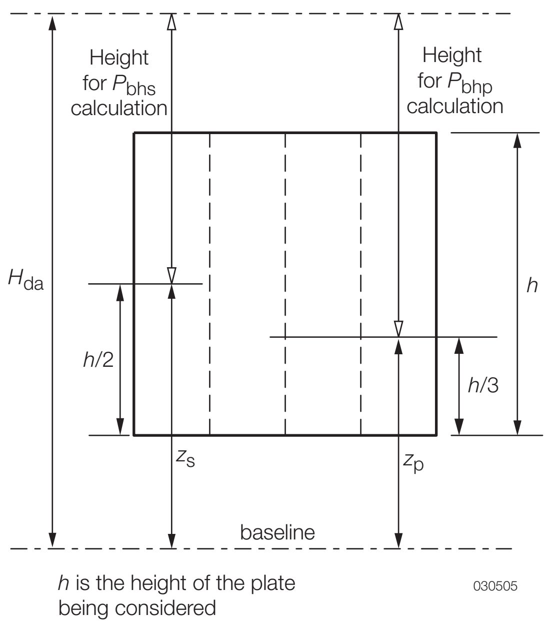


Fig. 3.5.5
***Z*, distance above baseline for pressure head for plating with vertical stiffeners**

5.9 Design pressures for collision bulkheads

5.9.1 The design lateral pressure height for collision bulkheads, H_{cb}, is to be taken as:

H_{cb} = the vertical distance, in m, from the baseline to 0,91 m above the uppermost point of the collision bulkhead.

5.9.2 The design normal pressure for the collision bulkhead plating, P_{bhp}, is to be taken as:

$P_{bhp} = 10\,(H_{cb} - z_p)$ kN/m^2

where

z_p = distance above baseline of a point one third of the height, above the lower edge, of the plate strake under consideration.

5.9.3 The design normal pressure for bulkhead stiffeners, P_{bhs}, is to be taken as:

$P_{bhs} = 10\,(H_{cb} - z_s)$ kN/m^2

where

z_s = distance above base of the mid-span of the vertical stiffener under consideration, *see* Fig. 3.5.5

or

z_s = distance above base of the mid-span of the horizontal stiffener under consideration, *see* Fig. 3.5.4.

5.9.4 The collision bulkheads are to be designed to the deep tank design criteria specified in Pt 6, Ch 5.

5.9.5 If there is a design requirement for the ship to be able to remain operational after an incident which results in the collision bulkhead becoming the primary watertight boundary to the sea, then it will be necessary to design the collision bulkhead using the pressures for the shell envelope, P_s, given in Section 3 and the shell envelope design criteria. It will also be necessary to consider the effects of wave impact pressures, *see* 4.3, using the design speed requirement after damage.

5.10 Design loads for RSA notation assessment

5.10.1 The capability of transverse bulkheads, longitudinal bulkheads, watertight decks and other structure to withstand any additional loads as a consequence of damage, e.g. sloshing loads on watertight bulkheads, may need to be specially considered. Pressure heads consistent with draughts and heel angles determined from the damage stability analyses are to be used for local scantling assessment.

5.10.2 Where the Naval Authority requires watertight boundaries for damage control purposes, the nominated decks are to be assigned as watertight boundaries, *see* Pt 6, Ch 3,10. The pressure heads used in the assessment of damage control decks are to be the greater of that determined from the Rules or that specified by the Naval Authority.

5.10.3 The local design loads for structures subjected to additional loading as a consequence of structural damage are to be taken as specified in this Chapter except that the wave height factor, f_{Hs}, may be reduced, to account for the lesser environmental requirements, as follows:

f_{Hs} may be reduced by a factor of 1,85

where

f_{Hs} is defined in 1.2.

5.10.4 Where local strength issues need to be considered, the following local loads are to be applied in the evaluation contained in Pt 6, Ch 4,4.1:

- Hydrostatic load due to flooding taking account of the increase in local draft.
- Wave and inertial loads in the damaged condition, derived using the reduction factor given in 5.10.3.
- Local loads on watertight divisions as a consequence of flooding. For the evaluation of local loads on watertight divisions, the standard design pressure, H_{da} (*see* 5.7) may be applied. Alternatively the external hydrostatic and wave pressure load, P_s, may be applied using the reduction factor given in 5.10.3.
- Wave impact loads need not be considered unless a significant operational requirement is necessary following damage.

Section 6 Other local loads

6.1 General

6.1.1 This section gives formulations for design pressure loads for shell closing appliances and requirements for gravity and inertial loads due to equipment, payload, cargo, etc., acting on ramps and lifting appliances.

6.2 Loads for ramps and lifts, P_{ra}

6.2.1 The loads acting on ramps and lifts intended to be used at sea, P_{ra}, is to be derived as follows:

$P_{ra} = W_{cd} (1 + f_d (a_z + a_{ra}))$ kN/m^2

where

W_{cd} is the equivalent static pressure exerted by the cargo on the ramp or lift as specified by the designer in kN/m^2

a_z is the non dimensional vertical acceleration given in 2.3.2

a_{ra} = maximum acceleration of the lift, *see* 2.3

f_d = duty factor for the lift or ramp
= 2,0 for operation with personnel
= 1,5 otherwise.

6.2.2 If the hoisting speed of the ramp or lift is such that the acceleration of the lift will cause an increase in the forces acting on the lift, then this acceleration term should be included.

6.2.3 Where the lift or ramp is designed to operate totally or partially under water, then due consideration is to taken of the additional forces applied to the lift or ramp as a direct consequence of the water environment, e.g. added mass and velocity dependant damping forces.

6.3 Loads for windows and side lights in the shell envelope, P_{wi}

6.3.1 The design normal pressure, P_{wi}, for windows and side lights in deckhouses and superstructures is given by:

$P_{wi} = W_1 P_s$ kN/m^2

In no case is the design pressure for windows to be taken less than $P_{wi,min}$ as given by:

$P_{wi,min} = W_1 (10 + 0{,}04L_R)$ kN/m^2

where

W_1 = 1,33C_1

z = vertical distance, in metres, from baseline to the structural element being considered

P_s is to be taken at the height of the deck below the side light, *see* 3.2

C_1 is defined in 5.5.1

D and T are defined in 1.3.

Section 7 Ice loads

7.1 General

7.1.1 A half or full icing allowance is to be included in the local load calculation of ships that are required to operate for extended periods in areas where ice accretion is expected, *see* Pt 5,Ch 2,4.

7.2 Ice loads for full icing allowance

7.2.1 For local strength calculations of plating and stiffened panels a pressure additional to that normally required of 1 kN/m^2 (100 mm of ice) is to be applied to all exposed horizontal or near horizontal surfaces.

7.2.2 For local strength calculations of plating and stiffened panels a pressure additional to that normally required of 0,25 kN/m^2 (25 mm of ice) is to be applied to all exposed vertical surfaces.

7.3 Ice loads for half icing allowance

7.3.1 For local strength calculations of plating and stiffened panels a pressure additional to that normally required of 0,5 kN/m^2 (50 mm of ice) is to be applied to all exposed horizontal or near horizontal surfaces.

7.3.2 For local strength calculations of plating and stiffened panels a pressure additional to that normally required of 0,18 kN/m^2 (18 mm of ice) is to be applied to all exposed vertical surfaces.

Section

■ *Section 1* General

1.1 Introduction

1.1.1 The global design loads detailed in this Chapter are to be used in conjunction with Part 6 to determine the global hull strength requirements. The application of the global design loads is given in Pt 6, Ch 4.

1.1.2 Flowcharts showing the procedures for the specification of the global design loads are shown in Fig. 4.1.1.

1.1.3 The global design loads are divided into the following categories:

(a) Hull girder loads.
The types of hull girder loads which are to be considered for strength purposes in the initial design assessment are distinguished on the basis of their frequency of occurrence and are defined as follows:
   (i) Still water shear forces and associated bending moments arising from static mass distribution and buoyancy forces, *see* Section 2.
   (ii) Low frequency vertical wave shear forces and associated bending moments arising from hydrodynamic forces.
   (iii) High frequency dynamic shear forces and associated bending moments arising from slamming events.
The derivation of the hull girder loads is given in Section 3.

(b) Extreme hull girder loads.
The loads to be considered for extreme hull girder strength purposes are used to assess the hull girder structural capability to withstand extreme sea states. The derivation of the extreme hull girder loads is given in Section 4.

(c) Hull girder loads for residual strength assessment.
The loads to be considered for residual strength purposes are used to assess the structural capability of the ship after damage to withstand moderately severe sea states. The derivation of the residual strength hull girder loads is given in Section 5.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.2 Definitions and symbols

1.2.1 L_R, B, B_{WL}, D and T are defined in Pt 3, Ch 1,5. F_n and Δ are defined in Pt 5, Ch 3,1.3.2 and Pt 5, Ch 3,1.3 respectively.

1.2.2 For longitudinal strength calculations of vertical shear force and bending moment, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of the ship. Shear force is positive when the algebraic sum of all vertical forces aft of the position is positive. Hogging bending moments are to be taken as positive values.

1.3 Direct calculation procedures

1.3.1 The still water longitudinal strength values are to be derived using a suitable longitudinal strength calculation system.

1.3.2 In direct calculation procedures capable of deriving the wave induced loads on the ship account is to be taken of the ship's actual form and weight distribution.

1.3.3 Lloyd's Register (hereinafter referred to as 'LR')'s direct calculation method of the long term wave induced loads involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.3.4 The long term response predictions are to be based on probability of 10^{-8}. The LR long term prediction method produces values which have a low statistical probability of occurring taking into account many factors. These factors include:

- The operating life of the vessel, normally the operating life is taken as 20 years which is assumed to correspond to 10^8 wave encounters.
- The mission profile of the vessel.
- Different loading conditions.
- The effect of different wave headings on ship motions.

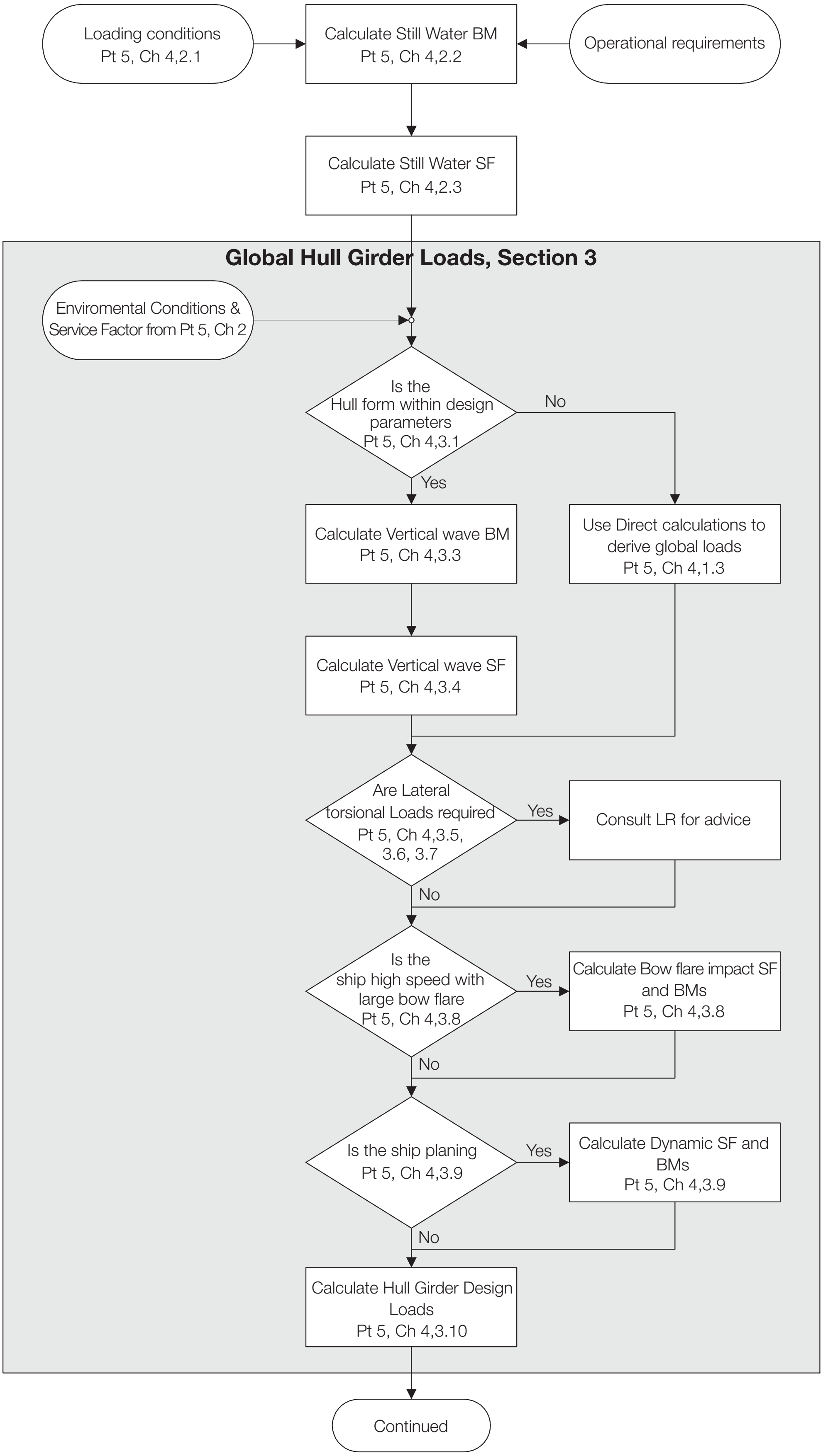


Fig. 4.1.1 Procedure for the specification of global design loads

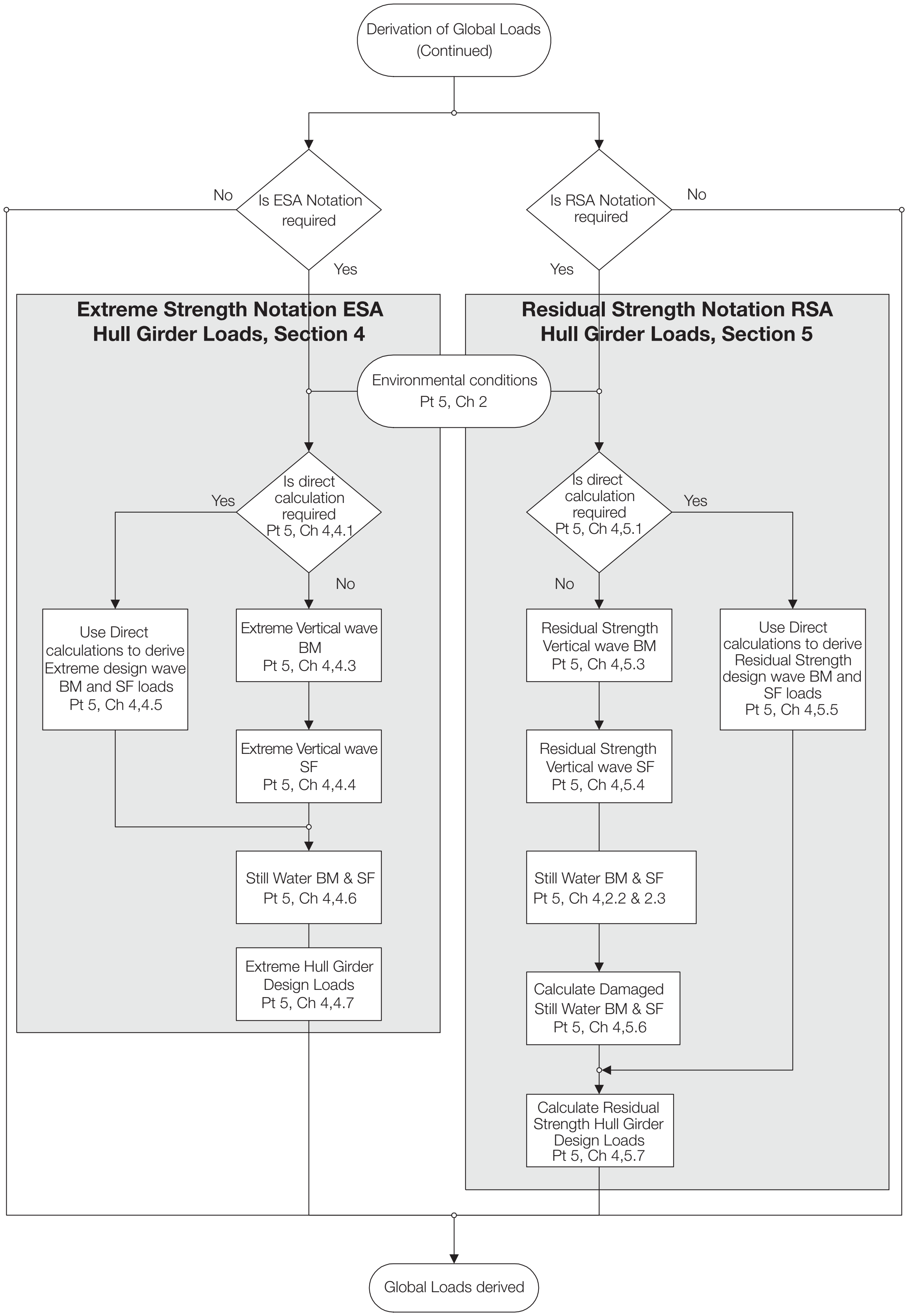


Fig. 4.1.1 Procedure for the specification of global design loads *(continued)*

1.4 Information required

1.4.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list showing details of the volume and position of centre of gravity of all tanks, spaces and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull together with a lines plan and/or tables of offsets.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions.
(e) Calculated still water bending moments and shear forces and the proposed design envelopes. Calculated wave and dynamic bending moment and shear force values.

1.4.2 It is recommended that this information be submitted in the form of a preliminary Loading Manual or Stability Information Book including: specification of operational requirements, hydrostatic data, details of loading conditions, etc. It may also be necessary to submit a summary of the damage stability analysis.

■ *Section 2* **Still water global loads**

2.1 General

2.1.1 The still water bending moments and shear force distributions are to be derived using a suitable direct calculation method for a range of loading conditions which cover the operational envelope of the ship.

2.1.2 In general, loading conditions based on amount of fuel, fresh water, stores and payload at departure, arrival and during special operations are to be considered. Loading conditions representing special operational requirements are also to be considered.

2.1.3 As a minimum the following conditions are to be considered in deriving the maximum hogging and sagging still water bending moment and shear force envelopes:

- Deep draught (departure) condition with no growth margin.
- Light draught (arrival) condition with no growth margin.
- Deep draught condition with full growth margin.
- Light draught condition with full growth margin.
- Maximum and minimum operating draught conditions, if different to the above.
- Ballast conditions, where appropriate.
- Any special mid-voyage conditions caused by changes in payload or ballast distribution.
- Other special loading conditions, e.g. Emergency evacuation or similar emergency scenario conditions, heavy payloads or cargo, deck cargo conditions, etc., where applicable.

2.1.4 For special loading conditions which may only be required in restricted operational areas, a reduced service area factor, f_S, may be allowable, *see* 3.3.1.

2.1.5 If the still water bending moment and shear force envelope approach is not appropriate, (as a consequence of the envelope being too severe due to one or two special conditions distorting the envelope) then individual consideration of the bending moment and shear force will be necessary.

2.1.6 For ships that are designed to operate for extended periods in areas where ice accretion is expected, *see* Pt 5, Ch 2,4, a full or half icing allowance may need to be included in the still water bending moment and shear force calculation.

2.1.7 A full icing allowance is defined as a thickness of 100 mm of ice (1 kN/m^2) applied to all exposed horizontal or near horizontal surfaces. A thickness of 25 mm of ice (0,25 kN/m^2) applied to all exposed vertical surfaces. The centre of gravity of the ice is to be taken as that of an equivalent head of water. The density of ice is assumed to be 1000 kg/m^3.

2.1.8 A half icing allowance is the same as that applied for a full icing allowance but with a thickness of 50 mm (0,5 kN/m^2) for horizontal and 18 mm (0,18 KN/m^2) for vertical surfaces.

2.1.9 To account for miscellaneous fittings such as stanchions and rails an additional 5% should be added to the total ice weight calculated for both full and half icing allowances.

2.2 Still water bending moments

2.2.1 The design still water hogging and sagging bending moment distribution envelope, M_S, is to be taken as the maximum sagging (negative) and maximum hogging (positive) still water bending moments, in kN m, calculated at each position along the ship. The maximum moments from all loading conditions are to be used to define the still water bending moment distribution envelope.

2.2.2 It is normal for ships which have low deadweight requirements, e.g. frigates, to have a bending moment distribution envelope which is always hogging. In this case the maximum sagging bending moment envelope may be taken as the minimum hogging bending moment.

2.3 Still water shear forces

2.3.1 The design still water shear force distribution envelope, Q_S, is to be taken as the maximum positive and negative shear force values, in kN, calculated at each position along the ship. The maximum shear forces from all loading conditions, *see* 2.2, are to be used to define the still water shear force distribution envelope.

2.3.2 It is recommended that the minimum shear force value over the midships region should not be less than 50 per cent of the maximum value.

Section 3 Global hull girder loads

3.1 General

3.1.1 The global hull girder loads specified here are applicable to all displacement mono-hull naval ships as defined in Pt 1, Ch 2,2.2.5. These loads are to be used in the hull girder strength assessment given in Pt 6, Ch 3.

3.1.2 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:

Froude number > 0,8 (based on V_{sp}, *see* Ch 3,1.3.1)
$L_R/B_{WL} \leq 5$, or $B_{WL}/D \geq 2{,}5$
Unusual hull weight distribution
Unusual type or design.

3.2 Environmental conditions

3.2.1 The environmental conditions given in Chapter 2 are to be used in the derivation of the global hull girder loads.

3.3 Vertical wave bending moments

3.3.1 The minimum value of vertical wave bending moment, M_W at any position along the ship may be taken as follows:

$M_w = F_f\, D_f\, M_o$ kNm

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the ship above the waterline.

F_{fS} is the sagging (negative) moment correction factor and is to be taken as

$F_{fS} = -1{,}10\, R_A^{0,3}$ for values of $R_A \geq 1{,}0$
$F_{fS} = -1{,}10$ for values of $R_A < 1{,}0$

An area ratio value of 1,0 results in a sagging correction factor of –1,10.

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

$$F_{fH} = \frac{1{,}9C_{b1}}{(C_{b1} + 0{,}7)}$$

R_A is an area ratio factor, *see* 3.3.2.

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0{,}4L_R$ and $0{,}65L_R$
= 0 at forward end of L_R
Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1 L_f\, f_s\, L_R^2\, B_{WL}\, (C_{b1} + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$ for $L_R \leq 90$ m

$= 10{,}75 - \left(\frac{300 - L_R}{100}\right)^{1,5}$ for $L_R > 90$ m

$= 10{,}75$ for $L_R > 300$ m

$= 10{,}75 - \left(\frac{L_R - 350}{150}\right)^{1,5}$ for $L_R > 350$ m

f_s = Service area factor applicable to the Service Area Notation. To be specially considered depending upon the required areas of operation and in any event should be not less than 0,5
For unrestricted sea-going service $f_s = 1{,}0$, for other Service Areas Notations, *see* Ch 2,2.4

B_{WL} = maximum waterline breadth, *see* 1.2.1

C_{b1} = C_b but is not to be taken less than 0,60

C_b = the block coefficient as defined in Pt 3, Ch 1,5.

3.3.2 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\,(A_{BF} + 0{,}5A_{SF})}{L_R\, B_{WL}}$$

where

A_{BF} is the bow flare area, in m^2, *see* 3.3.3
A_{SF} is the stern flare area, in m^2, *see* 3.3.4

3.3.3 The bow flare area, A_{BF}, is illustrated in Fig. 4.3.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m^2

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0{,}8L_R$ from the AP

A_{LB} = half the water plane area at the design draught of the bow region of the hull forward of $0{,}8\,L_R$ from the AP.
Note the AP is to be taken at the aft end of the Rule length, L_R
The design draught is to be taken as T, *see* Ch 3,1.3.1

Alternatively the following formula may be used

$A_{BF} = 0{,}05L_R\,(b_0 + 2b_1 + b_2) + b_0\, a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at the FP, in metres, *see* Fig. 4.3.1

b_1 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at $0{,}9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at $0{,}8L_R$ from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken $L_f/2$ m above the design draught

$$T_{C,U} = T + \frac{L_F}{2} \text{ m}$$

L_f is given in 3.3.1
For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

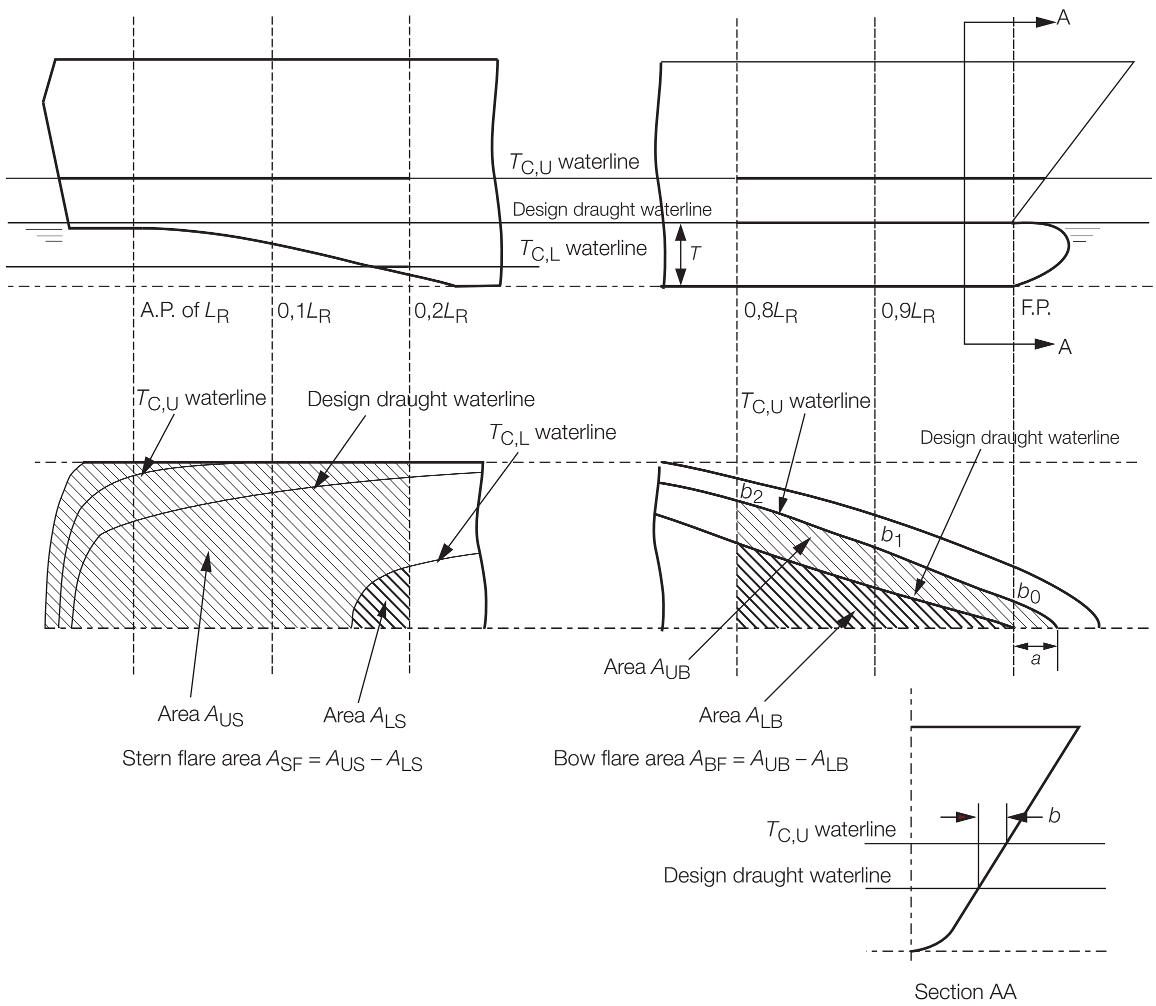


Fig. 4.3.1 Derivation of bow and stern flare areas

3.3.4 The stern flare area, A_{SF}, is illustrated in Fig. 4.3.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m^2

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to 0,2 L_R forward of the AP

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to 0,2 L_R forward of the AP

$T_{C,L}$ is a waterline taken L_f/2 m below the design draught

$$T_{C,L} = T + \frac{L_f}{2} \text{ m}$$

For ships with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

3.3.5 Alternatively, for frigate and destroyer type ships the hogging and sagging vertical wave bending moments and shear forces may be derived from long term 'in-service' measurements of a series of ships with similar hull forms, mass distributions and areas of operation. Typically this will be based on a static wave balance approach. The longitudinal distribution of the vertical wave bending moment is to be taken in accordance with the longitudinal distribution factor, D_f.

3.3.6 The vertical wave bending moments and associated shear forces are not to be taken as less than that given by 3.3.1 and 3.4.1.

3.3.7 Direct calculation methods may be used to derive the vertical wave bending moments, *see* 1.3.

3.3.8 The sagging correction factor, f_{fS}, in the vertical wave bending moment formulation in 3.3.1 may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

3.4 Vertical wave shear forces

3.4.1 The wave shear force, Q_W, at any position along the ship is given by:

$$QW = \frac{3K_f M_o}{L_R} \text{ kN}$$

where K_f is to be taken as follows, *see also* Fig. 4.3.2

(a) Positive shear force:

K_f = 0 at aft end of L_R
= $+0{,}836F_{fH}$ between $0{,}2L_R$ and $0{,}3L_R$
= $+0{,}65F_{fH}$ between $0{,}4L_R$ and $0{,}5L_R$
= $-0{,}65F_{fS}$ between $0{,}5L_R$ and $0{,}6L_R$
= $-0{,}91F_{fS}$ between $0{,}7L_R$ and $0{,}85L_R$
= 0 at forward end of L_R

(b) Negative shear force:

K_f = 0 at aft end of L_R
= $+0{,}836F_{fS}$ between $0{,}15L_R$ and $0{,}3L_R$
= $+0{,}65F_{fS}$ between $0{,}4L_R$ and $0{,}5L_R$
= $-0{,}65F_{fH}$ between $0{,}5L_R$ and $0{,}6L_R$
= $-0{,}91\ F_{fH}$ between $0{,}7L_R$ and $0{,}85L_R$
= 0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

M_o, F_{fH} and F_{fS} are defined in 3.3.1.

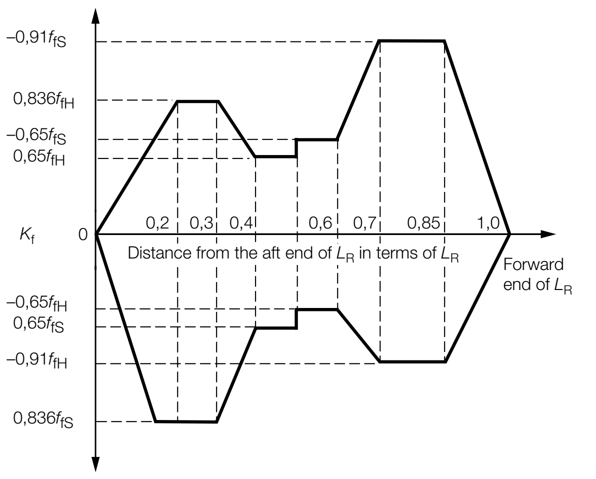


Fig. 4.3.2 Shear force factor K_f

3.4.2 The direct calculation method used to derive the vertical bending moments may also be used to derive the vertical shear forces, *see* 1.3.

3.5 Lateral wave bending moments

3.5.1 If considered necessary by LR, the effects of lateral bending moments may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant lateral stresses.

3.6 Lateral wave shear forces

3.6.1 If considered necessary by LR, the effects of lateral shear forces may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant lateral stresses.

3.7 Torsional moments

3.7.1 If considered necessary by LR, the effects of torsional moments may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant torsional stresses.

3.8 Bow flare impact global loads

3.8.1 The requirements of this section are applicable to fast ships operating in the displacement mode that satisfy the following requirements:

speed V_{sp} > 17,5 knots
bow shape factor ψ > 0,15

where

$$\psi = \frac{100A_b\, k_{fr}}{L_R^{1,5}\, B_{WL}}$$

A_b = bow flare area, *see* 3.8.2
k_{fr} = bow freeboard correction factor
$k_{fr} = \dfrac{6}{h_{fr}}$ but is to be not less than 0,5 nor greater than 1,5
h_{fr} = freeboard height to the upper deck measured at the FP, in metres

For ships with knuckles in the bow flare region above which the hull is nearly vertical or exhibits tumblehome, the values of h_{fr} and A_b are normally to be based on the bow flare region below the knuckle

L_R and B_{WL} are as defined in 1.2.1
V_{sp} is defined in Ch 3,1.3.

3.8.2 The bow flare area is normally to be derived as follows:

$$A_b = 0{,}05L_R\,(a_0 + 2a_1 + a_2) + a_0\, b/2 \ \text{ m}^2$$

where

a_0 = projection of deck at waterline at the FP, in metres
a_1 = projection of deck at waterline at $0{,}9L_R$, in metres
a_2 = projection of deck at waterline at $0{,}8L_R$, in metres
b = projection of upper deck at waterline from the FP to stem, in metres

see Fig. 4.3.3.
L_R is given in 1.2.1.

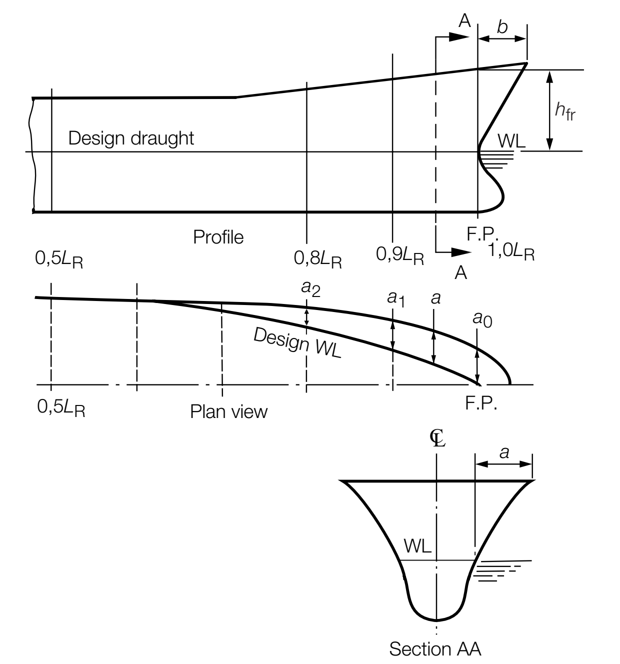


Fig. 4.3.3 Derivation of bow shape

3.8.3 The dynamic sagging bending moment due to bow flare impact loads, M_{BF}, is given by the following:

M_{BF} = $-33D_{bf}\,A_b\,k_{fr}\,L_R$ kNm

where

D_{bf} = the longitudinal distribution factor, *see* Table 4.3.1

A_b is given in 3.8.2

k_{fr} is given in 3.8.1

L_R is given in 1.2.1.

It is not required to consider a hogging bow flare impact bending moment.

Table 4.3.1 Longitudinal distribution factor D_{bf}

Position	Longitudinal distribution factor D_{bf}
$0,0L_R$	0,00
$0,4L_R$	1,00
$0,5L_R$	1,00
$0,6L_R$	0,98
$0,7L_R$	0,95
$0,8L_R$	0,81
$0,9L_R$	0,44
$1,0L_R$	0,00

NOTES
1. Intermediate values to be obtained by interpolation.
2. L_R as defined in 1.2.1.

3.8.4 If the bow flare impact bending moment, M_{BF}, is greater than the wave bending moment, M_W, *see* 3.3.1, at any position along the length then M_W is to be replaced by M_{BF} at these positions.

3.8.5 The bow flare impact shear force, Q_{BF}, associated with the bow flare bending moment is to be taken as follows over the forward half length of the ship:

Q_{BF} = $132K_{bf}\,A_b\,k_{fr}$ kN

where K_{bf} is to be taken as follows:

Positive shear force

K_{bf} = 0,0 aft of $0,5L_R$
= 0,7 between $0,5L_R$ and $0,6L_R$
= 1,0 between $0,7L_R$ and $0,85L_R$
= 0,0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

Negative shear force

K_{bf} = 0,0 for the length of the ship, L_R

where

A_b is given in 3.8.2

k_{fr} is given in 3.8.1.

3.8.6 If the bow flare impact shear force, Q_{BF}, is greater than the wave shear force, *see* 3.4, at any position along the length then the wave shear force, Q_W, is to be taken as Q_{BF} at these positions.

3.9 Dynamic bending moments and associated shear forces

3.9.1 The requirements of this section are applicable to mono-hull ships when operating in the planing regime.

3.9.2 This section gives formulae for the derivation of the high frequency dynamic bending moment, shear forces and associated pressures. The bending moment and shear force values are to be used for the global design loads if they are greater than the values derived in accordance with 3.3 and 3.4.

3.9.3 The dynamic bending moment, due to a high speed planning craft landing on a wave crest amidships, at any position along the ship, is to be calculated using the following expression:

M_{DW} = $F_{df}\,D_{df}\,|M_d|$ kN/m

where

$|M_D|$ = $51\Delta\,L_R\,(16a_{op} - 4a_{bp} - 17a_{sp} - 5) \times 10^{-3}$ kN/m

F_{df} = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_{df} = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$
= 0 at forward end of L_R
Intermediate values of D_f are to be determined by linear interpolation

a_{op} = vertical acceleration at the LCG, in terms of g, as defined in Ch 3,2.4

a_{bp} = vertical acceleration at forward end of L_R, in terms of g, Ch 3,2.4

a_{sp} = vertical acceleration at aft end of L_R, in terms of g, Ch 3,2.4.

3.9.4 The non-dimensional vertical acceleration at the LCG, a_{op}, as defined in Ch 3,2.4, is not to be taken less than 1,0 for the purpose of determining the dynamic bending moment M_{DW}. If the values of a_{bp} and a_{sp} are unknown, the distributions given in Ch 3,2.4 are to be applied.

3.9.5 Bottom longitudinals within 0,4L_R of amidships are subjected to the following effective pressure, P_{ds}:

$$P_{ds} = 0{,}14 P_{dI} + 8T \quad \text{kN/m}^2$$

where
P_{dI} is as defined in Ch 3,4.5
T is defined in 1.2.1.

3.9.6 Bottom plating within 0,4L_R of amidships is subjected to the following effective pressure, P_{dp}:

$$P_{dp} = 0{,}175 P_{dl} + 10T \quad \text{kN/m}^2$$

3.9.7 The dynamic shear force, Q_{DW}, at any position along the ship is given by:

$$Q_{DW} = 4K_f M_D / L_R \quad \text{kN}$$

where
M_D is defined in 3.9.3
K_f is defined in 3.4.1.

3.10 Hull girder design loads

3.10.1 The Rule bending moment envelope, M_R, and associated shear force envelope, Q_R, for use with the scantling determination procedures in Pt 6, Ch 3 are to be determined as follows:

(a) The Rule vertical bending moment envelope, M_R, is to be taken as ($M_W + M_S$), as defined in 3.3 and 2.2, taking into account the hogging and sagging conditions.
(b) The Rule vertical shear force envelope, Q_R, is to be taken as ($Q_W + Q_S$), as defined in 3.4 and 2.3, taking into account the hogging and sagging conditions.

3.10.2 The values M_W and Q_W are to be replaced by M_{BF} and Q_{BF} if these are larger, *see* 3.4 and 3.8.6. Similarly, the M_W and Q_W are to be replaced by M_{DW} and Q_{DW} if these are larger.

■ *Section 4* Extreme hull girder loads

4.1 Introduction

4.1.1 The extreme hull girder loads specified in this section are applicable to all mono-hull naval ships for which the optional **ESA1** or **ESA2**, Extreme Strength Assessment, notation is required. The design criteria detailed in this section are to be used in conjunction with the extreme hull girder strength assessment procedure given in Pt 6, Ch 4,3.

4.1.2 The extreme hull girder loads are typical lifetime maximum values that a ship is likely to encounter if it was to be present in an extreme seastate in sea areas associated with its service area notation.

4.2 Environmental conditions

4.2.1 The environmental design criteria for extreme design analysis given in Chapter 2 are to be used to determine the extreme hull girder loads.

4.2.2 The hull girder loads for the extreme hull girder strength assessment for unrestricted service operation, i.e. service area notation **SA1**, are typical maximum loads that are predicted for extreme winter North Atlantic conditions in head seas at low forward speed.

4.2.3 For other service area notations, the hull girder loads for the extreme hull girder strength assessment are typical maximum loads that are likely to be encountered within the restricted operational area.

4.3 Extreme vertical wave bending moments

4.3.1 For all mono-hull ships, the extreme vertical wave bending moment, M_{WEX}, at any position along the ship is given by:

$$M_{WEX} = K_{fEX} M_W \quad \text{kN m}$$

where
M_W is given in 3.3
K_{fEX} = extreme scaling factor
= 1,5.

4.3.2 Alternatively the extreme hull girder strength assessment wave loads may be derived using direct calculation methods, model tests or similar taking into account the likely range of wave periods and the environmental conditions specified in Chapter 2.

4.3.3 In deriving the wave loads, the longitudinal distribution of the vertical wave bending moment is to taken in accordance with the longitudinal distribution factor, D_f, *see* 3.3.1. Where appropriate, the hogging and sagging correction factor, F_{fH} and F_{fS} given in 3.3.1, may be used to derive the hogging and sagging bending moments from a direct calculation.

4.3.4 Where requested by the Owner, the extreme hogging and sagging vertical wave bending moment or extreme scaling factor, K_{fEX}, may be derived from long term 'in-service' measurements from a series of ships with similar hull forms, mass distributions and areas of operation.

4.4 Extreme vertical wave shear forces

4.4.1 The extreme vertical wave shear force, Q_{WEX}, at any position along the ship is given by:

$$Q_{WEX} = K_{fEX} Q_W \quad \text{kN}$$

where
Q_W is given in 3.4
K_{fEX} = the extreme scaling factor, *see* 4.3.

4.4.2 Alternatively the method of derivation of the extreme wave shear force may be consistent with that used to derive the bending moments.

4.5 Direct calculation procedures

4.5.1 Direct calculation procedures may be used to derive the extreme hull girder loads. LR's calculation method of the extreme hull girder loads involves derivation of the short term maximum probable responses.

4.5.2 The extreme hull girder loads, M_{WEX} and Q_{WEX}, are to be based on the probable maximum values that are likely to be experienced during severe storms. The parameters of the severe seastate, i.e. significant wave height, wave period range and duration of storm, are given in Chapter 2.

4.6 Still water shear forces and bending moments

4.6.1 The still water hogging and sagging shear force and bending moment distributions for the extreme hull girder strength assessment are to be taken as the Q_S and M_S distributions defined in 2.3 and 2.2 respectively.

4.7 Extreme hull girder design loads

4.7.1 The extreme hull girder strength design bending moment, M_{REX}, and associated shear forces, Q_{REX}, for all naval ships are to be determined as follows:

(a) The extreme hull girder strength design bending moment, M_{REX}, is to be taken as (M_{WEX} + M_S), as defined in 4.3 and 4.6, taking into account the appropriate hogging and sagging conditions.

(b) The extreme hull girder strength design shear forces, Q_{REX}, is to be taken as (Q_{WEX} + Q_S), as defined in 4.4 and 4.6, taking into account the appropriate hogging and sagging conditions.

4.7.2 It is unnecessary to consider the effects of operating at high speed on the extreme design values for extreme hull girder strength. The requirements for bow flare impact global loads may be ignored in the derivation of M_{WEX} and Q_{WEX}.

■ *Section 5* Residual strength hull girder loads

5.1 Introduction

5.1.1 The residual strength hull girder loads specified in this section are applicable to all displacement mono-hull naval ships for which the optional **RSA1**, **RSA2** or **RSA3**, Residual Strength Assessment, notation is required. The design criteria detailed in this section are to be used in conjunction with the residual strength assessment procedure given in Pt 6, Ch 4,4.

5.1.2 The residual strength hull girder loads are used to assess the capability of the ship's global hull girder after suffering structural damage to meet specified global strength requirements. The effects of flooding, as a consequence of structural damage, on the static global bending moments and shear forces are also to be considered.

5.2 Environmental conditions

5.2.1 The environmental design criteria for residual strength analysis given in Pt 5, Ch 2,3 are to be used to determine the residual strength hull girder loads.

5.2.2 The global loads for the residual strength hull girder strength assessment for unrestricted service operation, i.e. service area notation **SA1**, are typical maximum loads that are predicted in North Atlantic sea conditions that have a probability of exceedance of 20 per cent. The loads predicted for the ship in head seas at low forward speed are to be considered.

5.2.3 For other service area notations, the global loads for the hull girder residual strength assessment are typical maximum loads that are likely to be encountered within the restricted operational area in sea conditions that have a 20 per cent probability of being exceeded.

5.2.4 The designer/builder may stipulate the environmental conditions to be applied to the residual strength assessment. In which case the residual strength notation will be assessed against the required performance level.

5.2.5 The residual strength area reduction factor, K_{fRS}, is given by the following:

$$K_{fRS} = 1{,}1 H_{rw}\, L_R^{-0{,}48}$$

where

H_{rw} is given in Ch 2,2.3.5.

5.3 Residual strength vertical wave bending moments

5.3.1 The residual strength wave loads may be derived from the formula given below. The residual strength vertical bending moment specified here is applicable to all mono-hull ships.

5.3.2 The residual strength vertical wave bending moment, M_{WRS}, at any position along the ship is given by:

$$M_{WRS} = K_{fRS}\, M_W \text{ kN m}$$

where

M_W is given in 3.3

K_{fRS} = Residual strength area reduction factor, *see* 5.2.5.

5.3.3 Alternatively the residual strength wave loads may be derived using direct calculation methods, model tests or similar taking into account the likely range of wave periods and the environmental conditions specified in 5.2.

5.3.4 In deriving the residual strength wave bending moment, the longitudinal distribution is to taken in accordance with the longitudinal distribution factor, D_f, *see* 3.3.1. Where appropriate, the hogging and sagging correction factors, F_{fH} and F_{fS} may be used to derive the hogging and sagging bending moments from a direct calculation.

5.3.5 For conventional ships, it is not normally necessary to consider the effects of flooded compartments on the wave bending moments and shear forces.

5.3.6 For bottom damage assessment as a result of grounding, the residual strength vertical wave bending moment may be based on a M_W value derived using a service area factor, f_s, for a **SA4** service area notation; provided that the ship will not be required to proceed beyond sheltered water. Similarly for other damage assessments which are restricted to sheltered water environments, provided that there is no requirement for operation outside sheltered water areas.

5.4 Residual strength vertical wave shear forces

5.4.1 The residual strength vertical wave shear force, Q_{WRS}, at any position along the ship is given by:

Q_{WRS} = K_{fRS} Q_W kN

where

Q_W is given in 3.4

K_{fRS} = residual strength area reduction factor, *see* 5.2.5.

5.4.2 Alternatively the method of derivation of residual strength wave shear forces is to be consistent with that used to derive the bending moments.

5.5 Direct calculation procedures

5.5.1 Direct calculation procedures may be used to derive the residual strength hull girder loads. LR's calculation method of the residual strength hull girder loads involves derivation of the short term maximum probable responses.

5.5.2 The residual strength hull girder loads are to be based on the probable maximum values that are likely to be experienced during moderately severe sea conditions. The parameters of the seastate, i.e. significant wave height, wave period range and duration of storm, are given in Chapter 2.

5.6 Damaged still water shear forces and bending moments

5.6.1 The still water hogging and sagging shear force, Q_{SRS}, and bending moment, M_{SRS}, distributions in the damaged condition are to be calculated taking into account any flooding of the ship as a consequence of damage. If no flooding occurs then the still water values are to be taken from 2.3 and 2.2 respectively.

If no flooding occurs

M_{SRS} = M_S kN m

Q_{SRS} = Q_S kN

or if flooding occurs

M_{SRS} = damaged still water bending moment, sagging (negative) and hogging (positive), in kN m

Q_{SRS} = damaged still water shear force, positive and negative, in kN.

5.6.2 The loading conditions used to derive the undamaged still water shear force and bending moment curves are to be used for the assessment of the damaged still water bending moments together with the addition of flood water in damaged compartments.

5.7 Residual strength hull girder design loads

5.7.1 The residual strength design vertical bending moment, M_{RRS}, and associated shear forces, Q_{RRS}, for all naval ships are to be determined as follows:

(a) The residual strength design bending moment, M_{RRS}, is to be taken as (M_{WRS} + M_{SRS}), as defined in 5.3 and 5.6, taking into account the appropriate hogging and sagging conditions.

(b) The residual strength design shear forces, Q_{RRS}, is to be taken as (Q_{WRS} + Q_{SRS}), as defined in 5.4 and 5.6, taking into account the appropriate hogging and sagging conditions.

5.7.2 Where it is required that the ship is to be capable of operating at high speed after damage, it may also be necessary to consider the effects of dynamic bending moments and shear forces.

■ *Section 6* Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every ship to enable the Commanding Officer or Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the ship's structure.

6.1.2 This information should include any limiting criteria that were applied to the structural design of the ship, e.g. the maximum and minimum still water bending moments, service area notation with details of service area restrictions.

6.1.3 This information is to be provided by means of a Stability Information Book or Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.4 An Operational manual which contains the ship's assigned operational envelope is to be provided on board, *see* Pt 1, Ch 2,2 and Ch 1,1.

6.2 Loading Manuals or Stability Information Books

6.2.1 A Loading Manual is to be supplied to all ships where longitudinal strength calculations have been required. *see* Pt 6, Ch 3,4.2 and Pt 6, Ch 4,2.1. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the ship and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.
(b) The allowable local loadings for the structure.
(c) Details of the carriage of any substances where there are constraints imposed by the use of an accepted coating in association with a system of corrosion control.
(d) Where the ship has the capability to significantly alter the draught forward by filling water ballast tanks, then a note saying: ‘Scantlings approved for minimum draught forward of...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Commanding Officer or Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.’

6.2.5 Where applicable, the Manual is also to contain the procedure for ballast exchange and sediment removal at sea and the correct use of tanks.

6.2.6 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved loading instrument is to be provided for all ships where L_R is greater than 65 m except as noted below. The following ships are exempt from this requirement:

(a) ships with very limited possibilities for variations in the distribution of cargo and ballast;
(b) ships with a regular or fixed operational pattern.

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR procedures for the approval of longitudinal strength and stability calculation programs.

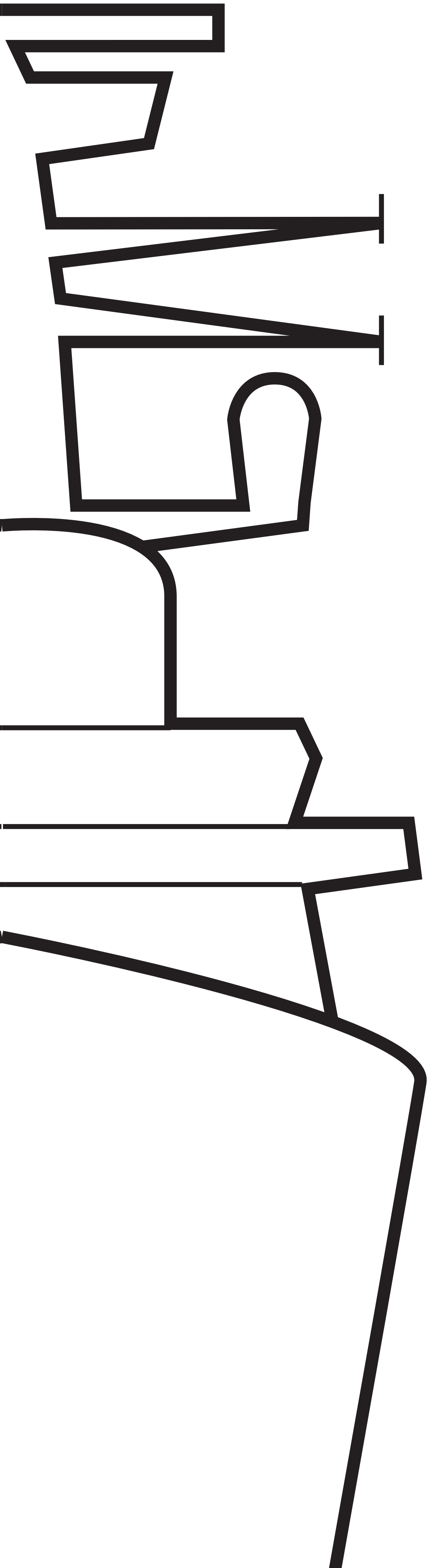
6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 Where the ship has the capability to significantly alter the draught forward by filling water ballast tanks, then a notice is to be displayed on the loading instrument stating: ‘Scantlings approved for minimum draught forward of... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Commanding Officer or Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.’

6.3.5 Where alterations to structure are carried out which result in a change in the lightweight or deadweight distribution, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner’s option, it is recommended that the system be certified in accordance with LR’s document entitled Approval of Longitudinal Strength and Stability Calculation Programs.



Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 6*

Hull construction in steel

January 2005

Lloyd's Register

Chapter Contents

Volume 1, Part 6

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Section 1 Application

1.1 General

1.1.1 The Rules apply to sea going monohull ships of normal form, proportions and speed. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 An overview of the structural design process is illustrated in Fig. 1.1.1.

1.2 Equivalents

1.2.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.3 Symbols and definitions

1.3.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

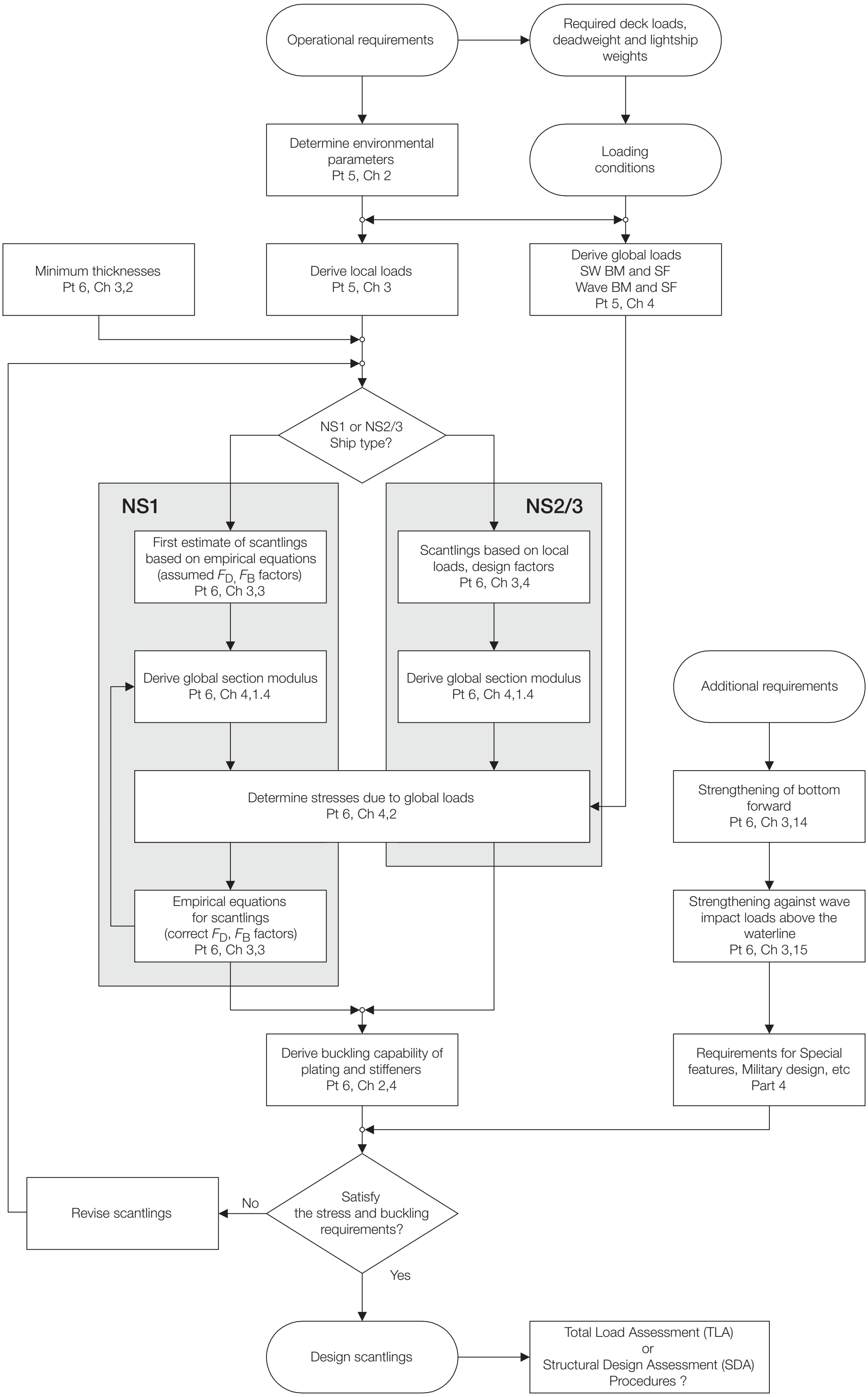


Fig. 1.1.1 Overview of the structural design process

Section 2
General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing ship types.

2.2 Plans to be submitted

2.2.1 Plans are to be of sufficient detail for plan approval purposes. For all areas of structure listed below the submitted plans are to show all plating thickness, stiffeners sizes and spacings, bracket arrangements and connections. Where appropriate, the plans should clearly show the allowance for corrosion margin or Owner's extra. Welding, constructional arrangements and tolerances are also to be submitted and this may be in the form of a booklet.

2.2.2 In general all items of steel structure are to be shown except where they are ineffective in supporting hull girder and local loads and do not impinge on such structure.

2.2.3 Equipment seating and supports are to be shown where they require additional stiffening and support to be incorporated in items of hull structure. In such cases the loading on the seating is also to be supplied. Generally total combined equipment weights on seating less than 0,5 tonnes need not be considered.

2.2.4 Normally the plans for each item will be able to be contained on a few sheets. Unit or production drawings will not be accepted.

2.2.5 Plans covering the following items are to be submitted:
- Midship and other critical sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Structural continuity plan showing shadow areas of openings, longitudinally effective material and primary structural continuity material.
- Oiltight and watertight bulkheads.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Storing routes.
- Deckhouses and superstructures.
- Propeller brackets and appendages.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals and stability information booklets, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable) including; location of anodes, method of attachment, details of cathodic protection system.
- Ice strengthening.
- Welding schedule.
- Hull penetration plans including scuppers, sea connections, overboard discharges, arrangements and fittings.
- Support structure for masts, derrick posts, cranes, RAS points, weapons handling/stowage or machinery lifting point and large items of equipment.
- Bilge keels showing material grades, welded connections and detail design.
- Flight deck arrangement and structure.

Additionally, for inwater survey the following plans and information are to be submitted:
- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the ship afloat.
- Details showing how stern bush clearances are to be measured with the ship afloat.
- Details of high resistant paint, for information only.

2.2.6 The following supporting documents are to be submitted:
- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.

2.2.7 The following supporting calculations are to be submitted:
- Equipment number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section and other critical section modulus.
- Structural items in the aft end, midship and fore end regions of the ship.

2.2.8 In the process of plan approval and from Fatigue Design Assessment and Structural Design Assessment certain critical locations may be identified which require special attention. Plans and records of production are to be submitted in accordance with the construction monitoring procedures associated with the notation CM.

2.2.9 Where the specific notations are applied for additional plans will be required.

2.3 Plans to be supplied to the ship

2.3.1 To facilitate the ordering of materials for repairs, plans listed in 2.4.1 are to be carried on board the ship. They are to clearly indicate the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and recommendations for welding, working and treatment of these steels.

2.3.2 Similar information is to be provided where aluminium alloy or other materials are used in the construction.

2.3.3 A copy of the final Loading Manual or Stability Information booklet, when approved, is to be placed on board the ship.

2.3.4 Details of any corrosion control system fitted are to be placed on board the ship.

2.3.5 Approved plans and information covering the items detailed in 2.2.5 relating to inwater survey are to be placed on board the ship.

2.4 Novel features

2.4.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of Lloyd's Register (hereinafter referred to as 'LR'), has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.5 Enhanced scantlings

2.5.1 Where scantlings in excess of the approved Rule requirement are fitted at defined locations as corrosion margins or for other purposes, as specified by the Owner, a notation **ES**, 'Enhanced Scantlings', will be assigned and it will be accompanied by a list giving items to which the enhancement has been applied and the increase in scantling. For example, the item 'bottom shell (strakes A, B, C, D)+2' will indicate that an extra 2 mm has been fitted to the bottom shell of the ship for the particular strakes listed, *see also* Pt 6, Ch 6,2.10. In addition the plans submitted for approval are to contain the enhanced scantling plan, together with the nominal thickness, less the enhancement adjacent, in brackets.

2.6 Direct calculations

2.6.1 Direct calculations may be specifically required by the Rules and may be required for ships having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7 Exceptions

2.7.1 Ships of unusual form, proportions or speed, with unusual features, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

Section

■ *Section 1* General

1.1 General

1.1.1 The guidance notes, information and formulae contained within this chapter are to be used in the scantling determination (Chapter 3) and total load assessment.

1.2 Equivalents

1.2.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.3 Symbols and definitions

1.3.1 The symbols used in this Chapter are defined below and in the appropriate Section:

Z = section modulus of stiffening member, in cm^3
I = moment of inertia, in cm^4
A_w = shear area of stiffener web, in cm^2
l = overall length of stiffener or primary member, in metres
l_e = effective span length, in metres, as defined in 2.6
p = design pressure, in kN/m^2
s = secondary stiffener spacing, in mm
S = primary stiffener spacing, in metres
t_p = plating thickness, in mm
β = panel aspect ratio correction factor as defined in 2.5
γ = convex curvature correction factor as defined in 2.4
k_s = higher tensile steel factor for local loads, *see* Ch 5,2.1.1
k_L = higher tensile steel factor for global loads, *see* Ch 5,2.1.2
σ_o = guaranteed minimum yield strength of the material, in N/mm^2
τ_o = shear strength of the material in N/mm^2

$$= \frac{\sigma_o}{\sqrt{3}}$$

E = modulus of elasticity, in N/mm^2.

1.4 Rounding policy for Rule plating thickness

1.4.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.5 Material properties

1.5.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:
(a) Yield strength (minimum) σ_o = 235 N/mm^2
(b) Tensile strength = 400–490 N/mm^2
(c) Modulus of elasticity, E = 200 x 10^3 N/mm^2.

1.6 Higher tensile steel

1.6.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.6.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, stiffener section modulus, inertia and cross-sectional area by the use of higher tensile steel correction factors k_s and k_L or f_{hts}. Normally, this allowance is included in the appropriate scantling requirements. Where this is not the case, the following correction factors may be applied:
(a) Plating thickness factor = $\sqrt{k_s}$ for local loads
$\sqrt{k_L}$ for global loads
(b) Section modulus and cross sectional area factor = k_s
where k_s and k_L are defined in 1.3.1
f_{hts} is defined in Ch 5,1.3.

1.6.3 Higher tensile steel may be used for both deck and bottom structures or deck structure only. Where fitted for global strength purposes, it is to be used for the whole of the longitudinal continuous material for the following vertical distances:
(a) z_{htd} below the line of deck at side

$$z_{htd} = \left(1 - \frac{k_L}{F_D}\right) z_D \text{ m}$$

(b) z_{htb} above the top of keel

$$z_{htb} = \left(1 - \frac{k_L}{F_B}\right) z_B \text{ m}$$

In the above formulae F_D and F_B are to be taken not less than k_L
where
F_D and F_B are defined in Ch 3,3.6. Note the F_D and F_B factors derived in Ch 3,3.6 for NS1 ships may also be applied to ship types NS2 and NS3.
z_D and z_B are the vertical distances, in m, from the transverse neutral axis of the hull cross-section to the uppermost continuous longitudinally effective material and to the top of the keel respectively.
k_L is defined in 1.3.1.

1.6.4 The designer should note that there is no increase in fatigue performance with the use of higher tensile steels.

■ *Section 2* Structural design

2.1 General

2.1.1 This Section gives the basic principals to be adopted in determining the Rule structural requirements given in Chapter 3.

2.1.2 For derivation of scantlings of stiffeners, beams, girders, etc., the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

2.1.3 The stiffener, beam or girder strength is defined by a section modulus and moments of inertia requirements. In addition there are local requirements for web thickness or flange thickness.

2.1.4 Some of the details given in this section will be specially considered for ships with a military distinction notation **MD**.

2.2 Effective width of attached plating, b_e

2.2.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

2.2.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm, and a breadth b_e, in mm.

2.2.3 The effective breadth of attached plating to secondary stiffener members b_e, is to be taken as:

$$b_e = 40 t_p \text{ mm}$$

or 600 mm, whichever is the greater
or the actual spacing of stiffeners in mm, whichever is the lesser.

2.2.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.), b_e, is to be taken as:

$$b_e = 300 S \left(\frac{l}{S}\right)^{2/3} \text{ mm but is not to exceed } 1000S.$$

where S and l are as defined in 1.3.1.

2.3 Section properties

2.3.1 The dimensions of rolled and built stiffeners are illustrated in Fig. 2.2.1. The section properties of stiffeners can be based on the illustrated dimensions if manufacturer's information is not available.

2.3.2 The effective section properties of a corrugation over a spacing b, *see* Fig. 2.2.2, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

Section modulus

$$Z = \frac{d_w}{6000} (3 b_e t_p + c t_w) \text{ cm}^3$$

Moment of inertia

$$I = \frac{Z}{10} \left(\frac{d_w}{2}\right) \text{ cm}^4$$

Shear area

$$A_w = \frac{d_w t_w}{100} \text{ cm}^2$$

where
d_w, b_f, t_p, c and t_w are measured, in mm, and are as shown in Fig. 2.2.2. The value of b_e is to be taken not greater than b_f or:

$50 t_p \sqrt{k_s}$ for welded corrugations

$60 t_p \sqrt{k_s}$ for cold formed corrugations

k_s = local high strength steel factor, *see* 1.3.1

The value of θ is to be not less than 40°.

2.3.3 The section properties of a double skin primary member over a spacing b, *see* Fig. 2.2.3, may be calculated as:

Section modulus

$$Z = \frac{d_w}{6000} (6 f b t_p + d_w t_w) \text{ cm}^3$$

Moment of inertia

$$I = \frac{Z}{10} \left(\frac{d_w}{2}\right) \text{ cm}^4$$

Shear area

$$A_w = \frac{d_w t_w}{100} \text{ cm}^2$$

where
d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 2.2.2

$$f = 0{,}3 \left(\frac{1000 l}{b}\right)^{2/3} \text{ mm but is not to exceed } 1{,}0$$

NOTE
If the plate flanges of the double bulkhead are of unequal thicknesses, then the equations in 2.3.4 may be used with $b_e = b_f = f\, b$.

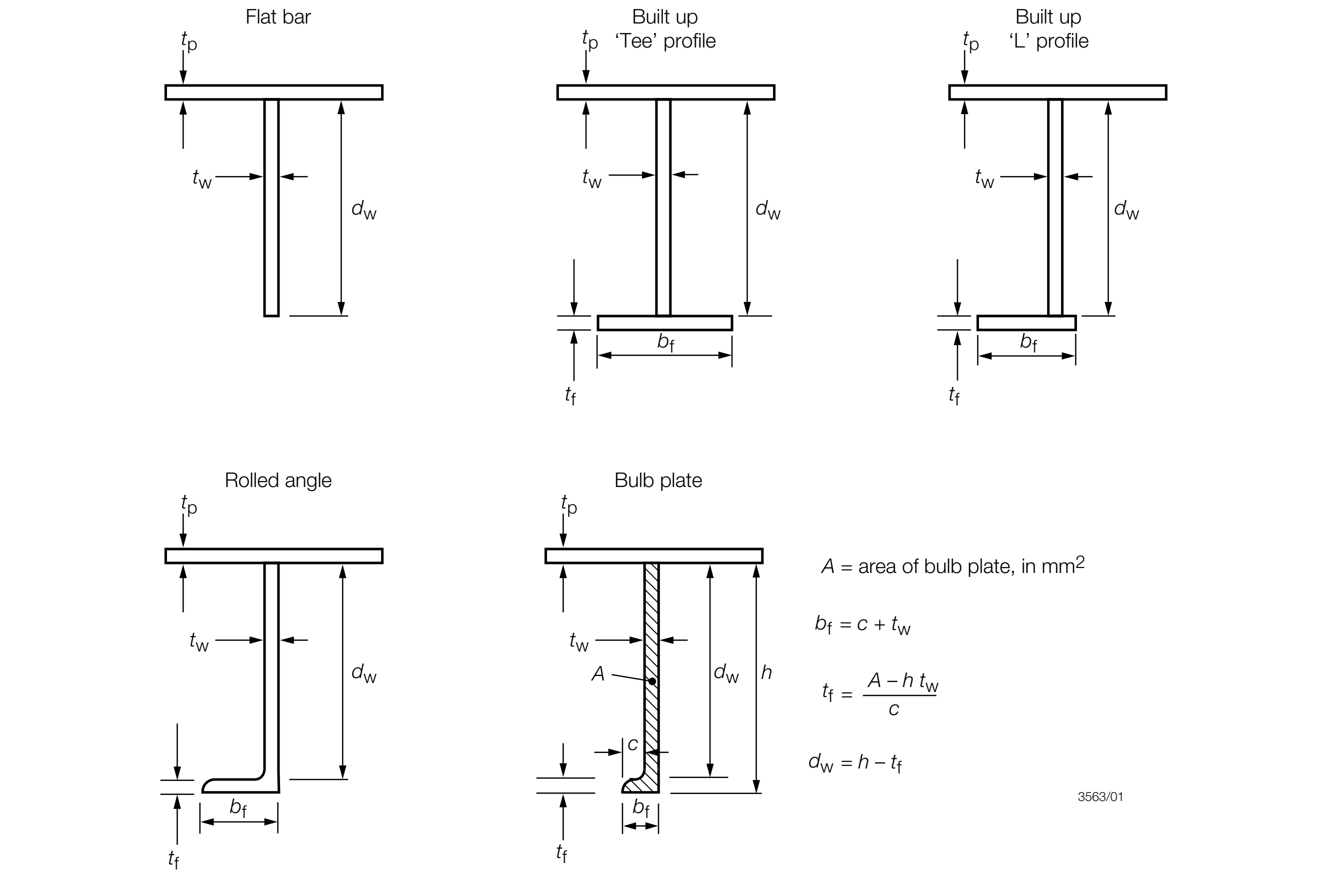


Fig. 2.2.1 Dimensions of longitudinals

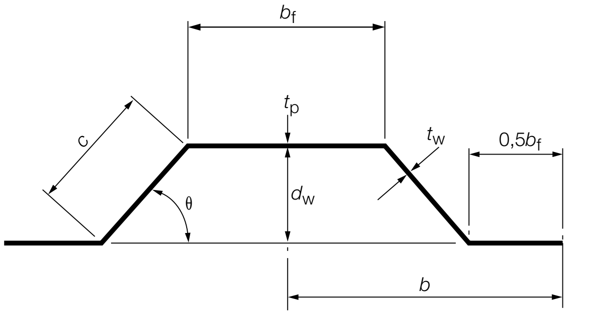


Fig. 2.2.2 Corrugated section

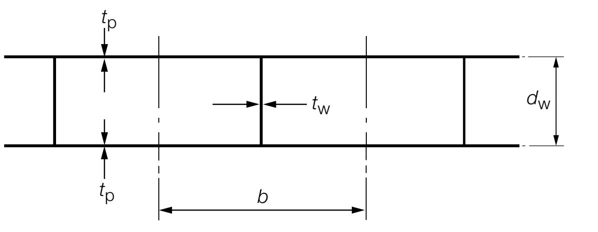


Fig. 2.2.3 Double skin section

2.3.4 The effective section properties of a built section, *see* Fig. 2.2.1, may be taken as:

Section modulus of flange

$$Z_f = \frac{A_f\,d_w}{10} + \frac{A_w\,d_w}{60}\left(1 + \frac{2\,(A_p - A_f)}{2A_p + A_w}\right)\ \text{cm}^3$$

Neutral axis of section above plating

$$x_{na} = \frac{d_w}{A}\left(\frac{A_w}{2} + A_f\right)\ \text{mm}$$

Moment of inertia about neutral axis

$$I = \frac{Z_f}{10}\,(d_w - x_{na})\ \text{cm}^4$$

Section modulus at plate

$$Z_p = 10\,\frac{I}{x_{na}}\ \text{cm}^3$$

Shear area

$$A_w = \frac{d_w\,t_w}{100}\ \text{cm}^2$$

where

A_f = area of face plate of flange in cm^2
A_w = area of web plating in cm^2
A_p = area of attached plating in cm^2, *see* 2.3.5
A = $A_f + A_w + A_p$
d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

b_e = effective breadth of attached plating, in mm, *see* 2.2

b_f, t_f, d_w, t_w and t_p are in mm and are illustrated in Fig. 2.2.1.

2.3.5 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) attached to corrugated bulkheads, are to be calculated in association with an effective area of attached load bearing plating, A_p, determined as follows:

(a) For a member attached to corrugated plating and parallel to the corrugations:
A_p = $b_f\, t_p/100$ cm^2
(*See* Fig. 2.2.2).

b) For a member attached to corrugated plating and at right angles to the corrugations:
A_p is to be taken as equivalent to the area of the face plate of the member.

2.4 Convex curvature correction

2.4.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - d_c/s_c$, and is not to be taken as less than 0,7

d_c = the distance, in mm, measured perpendicularly from the chord length, s_c, (i.e. spacing in mm) to the highest point of the curved plating arc between the two supports, *see* Fig. 2.2.4.

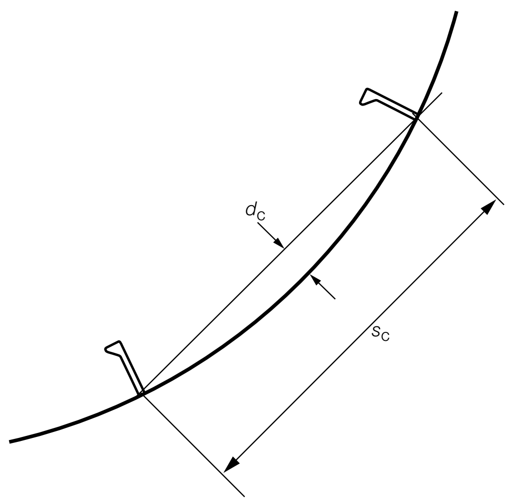


Fig. 2.2.4 Convex curvature

2.5 Aspect ratio correction

2.5.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R\,(1 - 0{,}25A_R)$ for $A_R \le 2$
= 1 for $A_R > 2$

A_R = panel aspect ratio
= panel length/panel breadth.

2.6 Determination of span length

2.6.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 2.2.5. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_s, from the end of the member

$$b_s = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_s, b_b, d_w and d_s are as shown in Fig. 2.2.5.

2.6.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

2.6.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

2.6.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

2.7 Plating general

2.7.1 The equation given in this sub section is to be used to determine the thickness of plating for NS2 and NS3 ship types. The design pressure, p, is given in the tables in Ch 3,4 for each structural component and is to be used with the limiting stress coefficient, *see* Ch 5,3.1.1, to determine the required plate thickness.

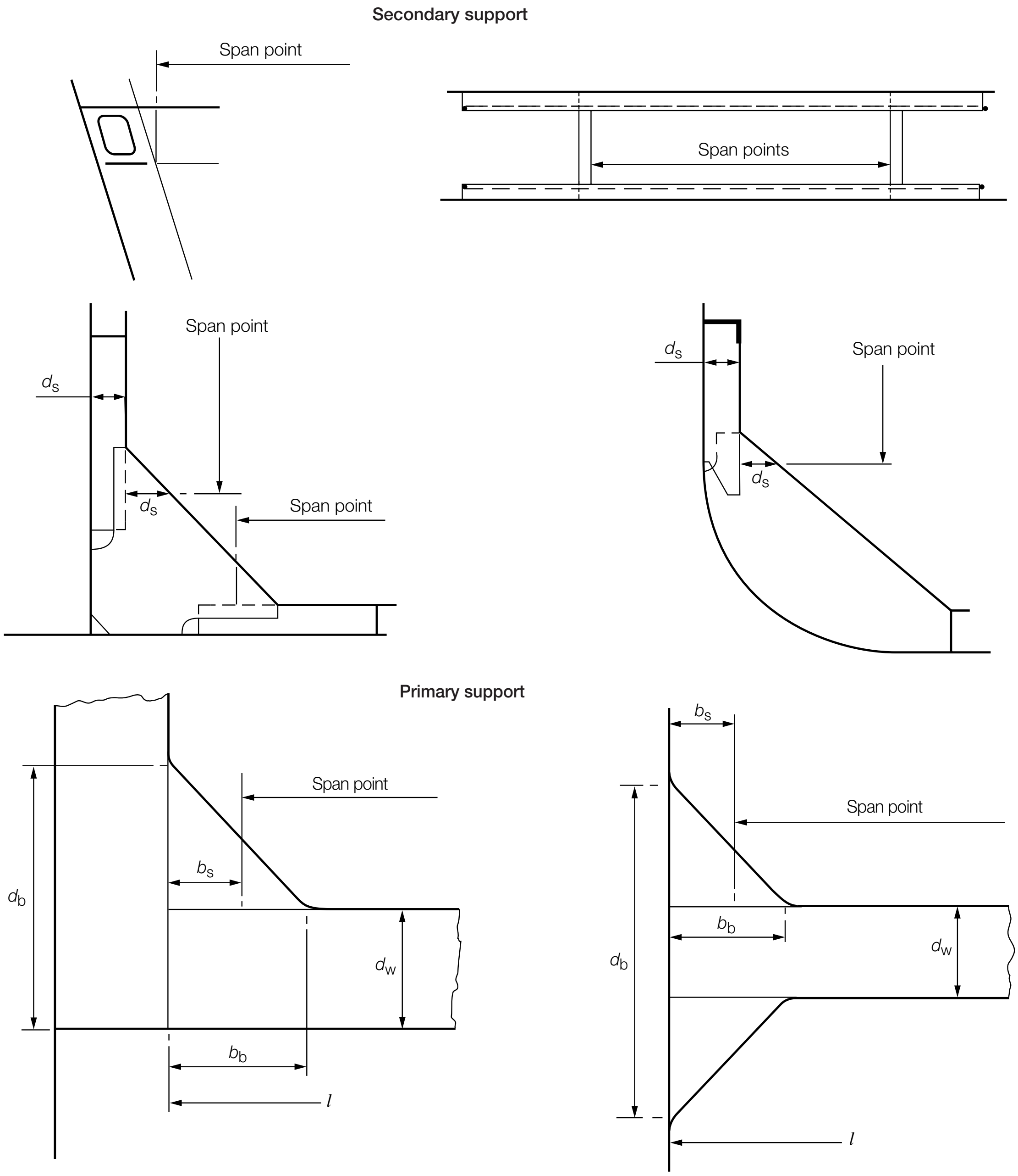


Fig 2.2.5 Definition of span points

2.7.2 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma\, \sigma_o}} \times 10^{-3} \text{ mm}$$

where

p is the design pressure, in kN/m^2, given in Ch 3,4

f_σ = limiting stress coefficient for local plate bending for the plating area under consideration given in Ch 5,3, σ_b column in Table 5.3.2, *see also* Ch 5,3.1.1

s, γ, β, σ_o are as defined in 1.3.1.

2.8 Stiffening general

2.8.1 The equations given in this sub section are to be used to derive the scantling requirements for stiffeners. The design pressure, p, is given in the tables in Ch 3,4 for each structural component and is to be used with the limiting stress coefficient, *see* Ch 5,3.1.1, to determine the required section modulus, web area and inertia of the stiffeners.

2.8.2 The requirements for section modulus, inertia and web area of stiffening members subjected to pressure loads are, in general, to be in accordance with the following:

(a) For secondary members:

Section modulus:

$$Z = \frac{\phi_Z\, ps\, l_e^2}{f_\sigma\, \sigma_o} \text{ cm}^3$$

Inertia:

$$I = \frac{100\, \phi_I\, ps\, l_e^3}{f_\delta\, E} \text{ cm}^4$$

Web area:

$$A_w = \frac{\phi_A\, ps\, l_e}{100\, f_\tau\, \tau_o} \text{ cm}^2$$

(b) For primary members:

Section modulus:

$$Z = \frac{10^3\, \phi_Z\, pS\, l_e^2}{f_\sigma\, \sigma_o} \text{ cm}^3$$

Inertia:

$$I = \frac{10^5\, \phi_I\, pS\, l_e^3}{f_\delta\, E} \text{ cm}^4$$

Web area:

$$A_w = \frac{10\, \phi_A\, pS\, l_e}{f_\tau\, \tau_o} \text{ cm}^2$$

where

p is the design pressure, in kN/m^2, given in Ch 3,4

ϕ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 2.2.1

f_σ = limiting local stiffener bending stress coefficient for stiffening member given in Ch 5,3.1.1, column σ_x in Table 5.3.2

ϕ_I = inertia coefficient dependent on the loading model assumption taken from Table 2.2.1

f_δ = limiting inertia coefficient for stiffener member given in Ch 5,3.1.1, column f_δ in Table 5.3.2

ϕ_A = web area coefficient dependent on the loading model assumption taken from Table 2.2.1

f_τ = limiting web area coefficient for stiffener member given in Ch 5,3.1.1, column f_τ in Table 5.3.2

E, S, s, l_e, σ_o and τ_o are as defined in 1.3.1.

2.8.3 The requirements for section modulus, inertia and web area of stiffening members subjected to point loads are, in general, to be in accordance with the following:

For primary and secondary members:

Section modulus:

$$Z = \frac{10^3\, \phi_Z\, F\, l_e}{f_\sigma\, \sigma_o} \text{ cm}^3$$

Inertia

$$I = \frac{10^5\, \phi_I\, F\, l_e^2}{f_\delta\, E} \text{ cm}^4$$

Web area

$$A_w = \frac{10\, \phi_A\, F}{f_\tau\, \tau_o} \text{ cm}^2$$

where

F is the design point load, in kN

ϕ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 2.2.1

f_σ = limiting local stiffener bending stress coefficient for stiffening member given in Ch 5,3.1.1, column σ_x in Table 5.3.2

ϕ_I = inertia coefficient dependent on the loading model assumption taken from Table 2.2.1

f_δ = limiting inertia coefficient for stiffener member given in Ch 5,3.1.1, column f_δ in Table 5.3.2

ϕ_A = web area coefficient dependent on the loading model assumption taken from Table 2.2.1

f_τ = limiting web area coefficient for stiffener member given in Ch 5,3.1.1, column f_τ in Table 5.3.2

E, l_e, and σ_o are as defined in 1.3.1.

2.8.4 Where a stiffener is subjected to a combination of loads, then the requirements are to be based on the linear supposition of those loads onto the stiffener. For example the section modulus requirement for a UDL load and a point load will be as follows:

$$Z = \frac{\phi_Z\, p\, s\, l_e^2}{f_\sigma\, \sigma_o} + \frac{10^3\, \phi_Z\, F\, l_e}{f_\sigma\, \sigma_o} \text{ cm}^3$$

2.9 Proportions of stiffener sections

2.9.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 2.2.2. For primary member minimum thickness *see* Table 6.5.1 in Pt 6, Ch 6.

2.9.2 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

2.9.3 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

2.9.4 Where the ratio of unsupported width of face plate (or flange) to its thickness exceeds 16:1, the tripping brackets are to be connected to the face plate and on members of symmetrical section, the brackets are to be fitted on both sides of the web.

2.9.5 Intermediate secondary members may be welded directly to the web or connected by lugs in accordance with Ch 6,5.3.

2.10 Grillage structures

2.10.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

2.10.2 General or special purpose computer programs or other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

Table 2.2.1 Section modulus, inertia and web area coefficients for different load models

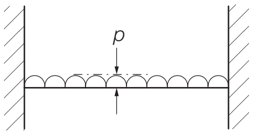
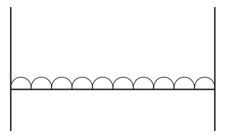
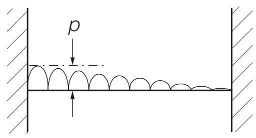
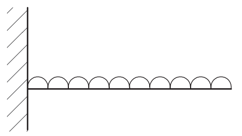
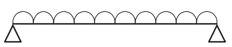
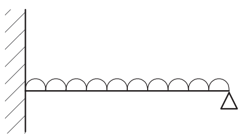
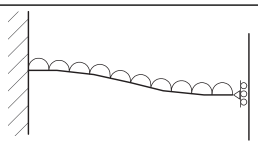
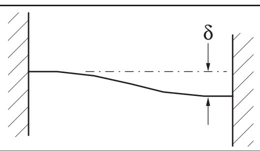
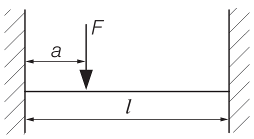
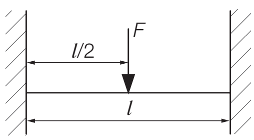
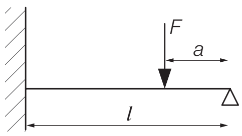
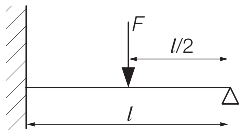
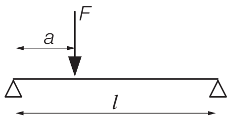
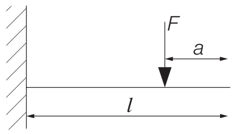
Load model	Position (j) 1 end	2 midspan	3 end	(j)	Web area coefficient ϕ_A	Section modulus coefficient ϕ_Z	Inertia coefficient ϕ_I	Application
(A)				1 2 3	1/2 – 1/2	1/12 –1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre Uniformly distributed pressure
(B)				1 2 3	1/2 — 1/2	1/10 –1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial Uniformly distributed pressure
(C)				1 2 3	7/20 — 3/20	1/20 — 1/30	— 1/764 —	Linearly varying distributed pressure Built in both ends
(D)				1 2 3	1 — —	1/2 — —	1/8 — —	Uniformly distributed pressure cantilevered beam
(E)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Uniformly distributed pressure Simply supported. Hatch covers, glazing and other members where the ends are not fixed
(F)				1 2 3	5/8 — 3/8	1/8 –9/128 —	— 1/185 —	Uniformly distributed pressure Cantilever plus simple support
(G)				1 2 3	1 — —	1/3 0 1/3	0 — 1/24	Uniformly distributed pressure Built in one end. Other end free to deflect but slope restrained
(H)				1 2 3	6 — 6	12 — 12	— — —	Built in both ends with forced deflection at one end
(I)				1 2 3	$\frac{(l-a)^2(l+2a)}{l^3}$ — $\frac{a^2(3l-2a)}{l^3}$	$\frac{a(l-a)^2}{l^3}$ $-\frac{2a^2(l-a)^2}{l^4}$ $\frac{a^2(l-a)}{l^3}$	— $\frac{2(l-a)^2a^3}{3(l+2a)^2l^3}$ —	Single point load, load anywhere in the span Built in at both ends
				1 2 3	1/2 — 1/2	1/8 –1/8 1/8	— 1/192 —	Single point load in the centre of the span Built in at both ends

Table 2.2.1 Section modulus, inertia and web area coefficients for different load models (*continued*)

Load model	Position (j): 1 end, 2 midspan, 3 end	(j)	Web area coefficient ϕ_A	Section modulus coefficient ϕ_Z	Inertia coefficient ϕ_I	Application
(J)		1	$\dfrac{a\,(3l^2 - a^2)}{2l^3}$	$\dfrac{a\,(l^2 - a^2)}{2l^3}$	—	Single point load, load anywhere in the span
		2	—	$\dfrac{-\,a\,(l - a)^2\,(2l + a)}{2l^4}$	$\dfrac{a\,(l - a)^2}{6l^3}\left(\dfrac{a}{2l + a}\right)^{1/2}$	Cantilever plus simple support
		3	$\dfrac{(l - a)^2\,(2l + a)}{2l^3}$	—	—	
		1	11/16	3/16	—	Single point load in the centre of the span
		2	—	5/32	1/108	
		3	5/16	—	—	Cantilever plus simple support
(K)		1	$\dfrac{l - a}{l}$	—	—	Single point load, load anywhere in the span
		2	—	$\dfrac{-\,a\,(l - a)}{l^2}$	$\dfrac{a}{3l^4}\left(\dfrac{l^2 - a^2}{3}\right)^{3/2}$	
		3	$\dfrac{a}{l}$	—	—	Simply supported
		1	1/2	—	—	Single point load in the centre of the span
		2	—	– 1/4	1/48	
		3	1/2	—	—	Simply supported
(L)		1	1	$\dfrac{(l - a)}{l}$	—	Single point load anywhere in the span
		2	—	—	—	
		3	—	—	$\dfrac{2l^3 - 3l^2\,a + a^3}{l^3}$	Cantilevered beam

NOTE
In all cases, the coefficient that results in the most pessimistic requirement is to be used in the stiffening equations in 2.8.

Table 2.2.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar continuous intercostal	Minimum web thickness: $t_w = d_w/18 \geq 2,5$ mm $t_w = d_w/15 \geq 2,5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/60 \geq 2,5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$

Symbols

t_w = web thickness of stiffener with unstiffened webs, in mm
d_w = web depth of stiffener, in mm
b_f = face plate (or flange) unsupported width, in mm
t_f = face plate (or flange) thickness, in mm

2.10.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

■ *Section 3* Detail design

3.1 Secondary member end connections

3.1.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 6,5 and Table 6.4.3.

3.1.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

3.1.3 The scantlings of secondary member end connections are to be in accordance with 3.2.

3.2 Scantlings of end brackets

3.2.1 For a naval ship, longitudinal strength members are to be continuous through primary supports. In exceptional cases for ships having a military distinction notation **MD** and in areas not subject to significant fatigue loading, longitudinal strength members may be cut at a primary support and the continuity of strength is to be provided by brackets. In such cases the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

3.2.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0,5L_R$ – modulus of the frame.
(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

3.2.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 2.9 are to be satisfied.

3.2.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 2.3.1.

3.2.5 The lengths, d_a and b_a, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $d_a + b_a \geq 2{,}0\, l_b$
(b) $d_a \geq 0{,}8\, l_b$
(c) $b_a \geq 0{,}8\, l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

3.2.6 The scantlings of deep web frames are based on the inclusion of the standard brackets specified in 3.2.5 at top and bottom, while the scantlings of side frames are normally to be based on a standard bracket at the top only. Where the actual arm lengths fitted, d_{a1}, and b_{a1} (in mm) are smaller than Rule size above or the bracket is omitted then, for comparison purposes, an equivalent arm length, l_a, is to be derived from:

(a) $l_a = \dfrac{(d_{a1} + b_{a1})}{2}$
(b) $d_{a1} \geq 0{,}8 l_a$
(c) $b_{a1} \geq 0{,}8 l_a$
(d) l_a = 0, where:
 (i) bracket is omitted from the upper or lower ends of the frame, or
 (ii) lower frame bracket at bilge is at same level as the inner bottom, or
 (iii) lower frame is welded directly to the inner bottom.

3.2.7 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 2000 cm^3.
(b) The length of free edge exceeds 50 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

3.2.8 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm but not less than 50 mm.}$$

3.2.9 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}009\, k_s\, b_f\, t_b$ cm^2 for offset edge stiffening.
(b) $0{,}014\, k_s\, b_f\, t_b$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm
t_b = the thickness of the bracket, in mm

k_s is as defined in 1.3.1.

3.2.10 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

3.2.11 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

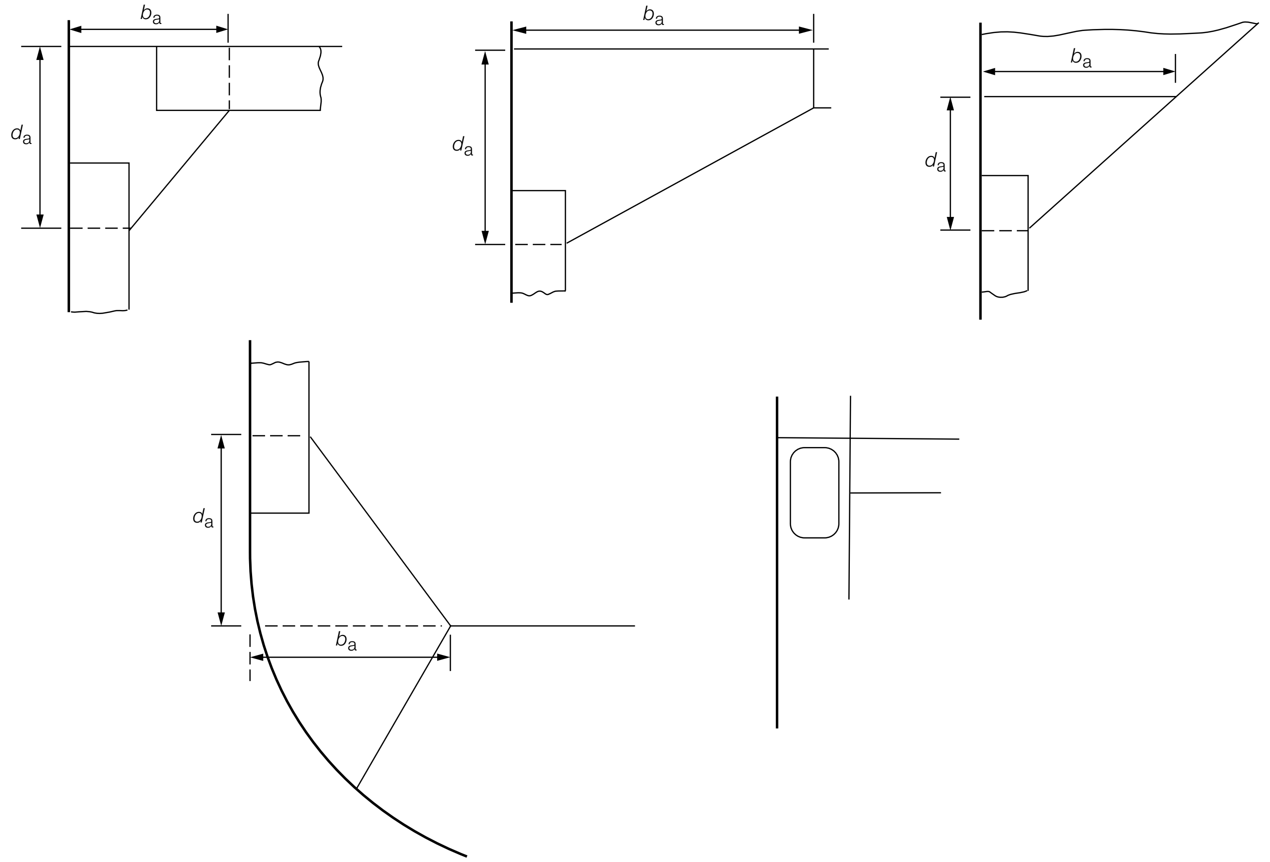


Fig. 2.3.1 Stiffener end brackets

3.2.12 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

3.2.13 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

3.2.14 The thickness of the bracket is to be not less than as required by Table 2.3.1.

Table 2.3.1 Thickness of end brackets

Bracket	Thickness, in mm	Limits	
		Minimum, in mm	Maximum, in mm
With edge stiffened:			
(a) in dry spaces	$3{,}5 + 0{,}25\sqrt{Z}$	6,5	12,5
(b) in deep tanks	$4{,}5 + 0{,}25\sqrt{Z}$	7,5	13,5
Unstiffened brackets:			
(a) in dry spaces	$5{,}5 + \left(\dfrac{Z}{55}\right) - \left(\dfrac{Z}{168}\right)^{1/3}$	7,5	
(b) in deep tanks	$6{,}5 + \left(\dfrac{Z}{55}\right) - \left(\dfrac{Z}{168}\right)^{1/3}$	8,5	

■ *Section 4* Buckling

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirement for buckling control of plate panels is contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as the global hull girder bending and shear stresses derived in accordance with Chapter 4. In addition, where the structural member is subject to local compressive loads, then the design stresses are to be based on these loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

A_R = panel aspect ratio

= $\dfrac{a}{b}$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1{,}9 t_p \sqrt{\dfrac{E}{\sigma_o}}$ or $0{,}8b$ mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres

S = spacing of primary member, in metres (measured in direction of compression)

4.3 Plate panel buckling requirements

4.3.1 The section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 2.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 2.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 2.4.2 are to be extracted from Chapter 5 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 2.4.2(a), and shear loads, Table 2.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/on shear loads are to be verified using the plate panel buckling requirements in Table 2.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation, *see* Ch 4,1.4.7 and 1.4.8.

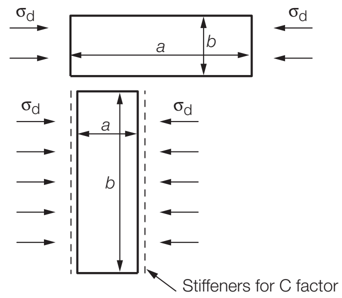
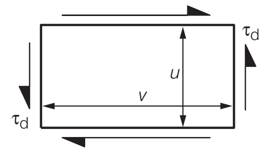
4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d), (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of the 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 2.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 2.4.1(b).

Table 2.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2 *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi\, E\left(\dfrac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\,\varphi\left(\dfrac{b}{a} + \dfrac{a}{b}\right)^2 E\left(\dfrac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\dfrac{u}{v}\right)^2\right) E\left(\dfrac{t_p}{u}\right)^2$ NOTE *u* is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

σ_c is defined in 4.2.1
σ_o is defined in 1.3.1

$$\tau_c = \tau_e \text{ when } \tau_e < \frac{\tau_o}{2}$$

$$= \tau_o\left(1 - \frac{\tau_o}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_o}{2}$$

τ_c is defined in 4.2.1
τ_o is defined in 1.3.1

Symbols and definitions

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and *b* are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \dfrac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.4.3 For welded plate panels with plating thicknesses below 8 mm, the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress for plating is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$
σ_c derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\,\beta_{RS}\,\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

t_p and σ_o are defined in 1.3.1
σ_c is derived in 4.4.1
b is defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,
$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \le \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors etc, may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \le \frac{1}{\lambda_\sigma}$$

where i = (a), (t), (w) or (f)

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where
σ_{de} is the stiffener axial stress given in 4.5.5
$\sigma_{c(i)}$ is given by Table 2.4.3
i is a, t, w or f depending on the mode of buckling.
λ_σ is the buckling factor of safety given in Table 5.3.2 in Chapter 5.

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\,\sigma_u}{\sigma_o} \text{ mm}$$

where
σ_u = ultimate buckling strength of plating as given in 4.5.4
σ_o is defined in 1.3.1
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \ge 1$:

$$\sigma_u = \sigma_o\left(\frac{1,9}{\Omega} - \frac{0,8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded i.e. $A_R < 1$:

$$\sigma_u = \frac{1,77\sigma_o A_R^{0,78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_o are defined in 1.3.1.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where
σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\,t}{100} \text{ cm}^2$$

where
b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$$

where
τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 5.3.2 in Chapter 5.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E\left(\frac{t}{s}\right)^2 \quad \text{for } A_R \ge 1$$

where

$$K_s = 4,5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$$

N = number of subpanels
$= \dfrac{1000S_p}{s}$

$$\omega = \frac{10I_{se}}{l\,t^3}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$$r = 1 - 0,75\left(\frac{s}{1000l}\right)$$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 2.4.1.

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in Table 2.4.1.

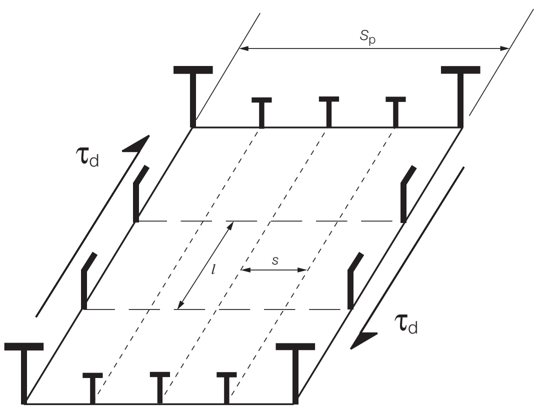


Fig. 2.4.1

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.1.3 and 4.5

λ_σ is the buckling factor of safety given in Table 5.3.2 in Chapter 5. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 3, Table 5.3.2.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 2.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 2.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this section are to be applied.

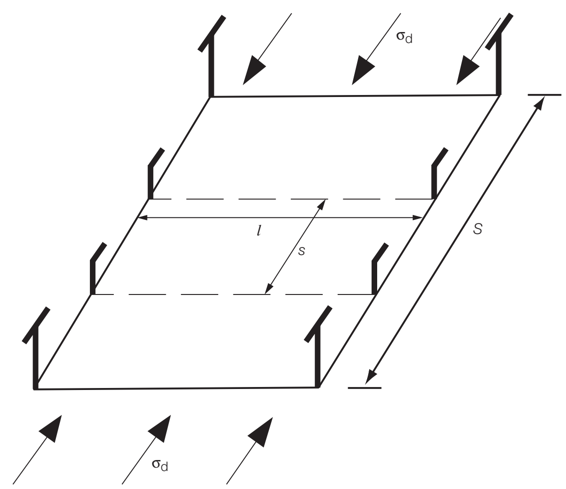


Fig. 2.4.2
Secondary stiffening perpendicular to direction compression

4.8.2 The minimum moment of inertia of each stiffener including attached effective plating of width, b_{eb}, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 - 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E} \text{ mm}^4$$

where

$D = \dfrac{E\,t_p^3}{12\,(1 - \upsilon^2)}$

$\kappa = A_R^2\,\Pi^2$

A_R = plate panel aspect ratio

$= \dfrac{s}{1000l}$

$\Pi = \dfrac{S}{l}$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in 4.2.1 and shown in Fig. 2.4.2.

t_p, *E* are defined in 1.3.1.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35\, S_p^4\, I_s}{l^3\, s} \times 10^3 \quad \text{cm}^4$$

S_p and s are as defined in 4.2.1

I_g is the sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the elastic column buckling mode specified in Table 2.4.3

$$= \frac{\sigma_{ep}\, A_{te}\, l_e^2}{0{,}001 E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \quad \text{N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_o}{2}$$

$$= \frac{\sigma_o^2}{4\,(\sigma_o - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm^2

σ_o and A_{te} are as defined in 4.2.1.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 1.3.1

l_e is defined in Table 2.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 2.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in Table 2.4.1.

$$\tau_e = 3{,}62 \left(1{,}335 + \left(\frac{d_w}{1000\, l_p}\right)^2\right) E \left(\frac{t_p}{d_w}\right)^2 \quad \text{N/mm}^2$$

where

d_w = web height, in mm

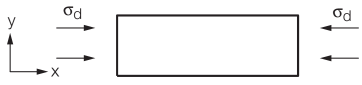
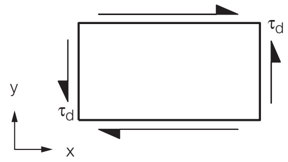
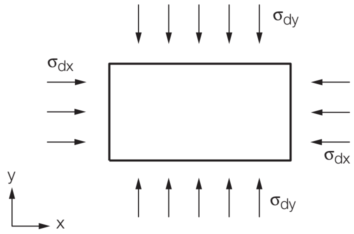
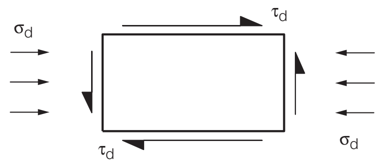
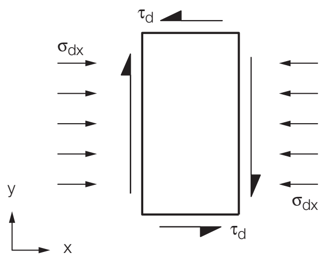
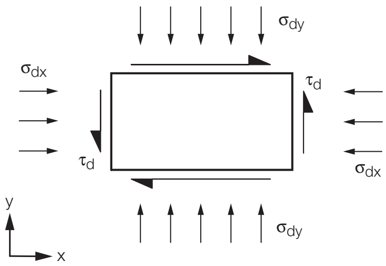
l_p = unsupported length of web, in metres

t_p and E are defined in 1.3.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,12.

Table 2.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\dfrac{\sigma_d}{\sigma_c} \le 1{,}0 \; \dfrac{1}{\lambda_\sigma}$	
(b)	shear loads	$\dfrac{\tau_d}{\tau_c} \le \dfrac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for $A_R = 1{,}0$ $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \le 1{,}0$ for other aspect ratios, i.e. $A_R \ne 1{,}0$ $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from Fig. 2.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\dfrac{1 + 0{,}6A_R}{1{,}6}\right)\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\dfrac{0{,}625\left(1 + \dfrac{0{,}6}{A_R}\right)\left(\dfrac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0{,}625\left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} + \dfrac{\left(\dfrac{\tau_d}{\tau_c}\right)^2}{1 - \left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5

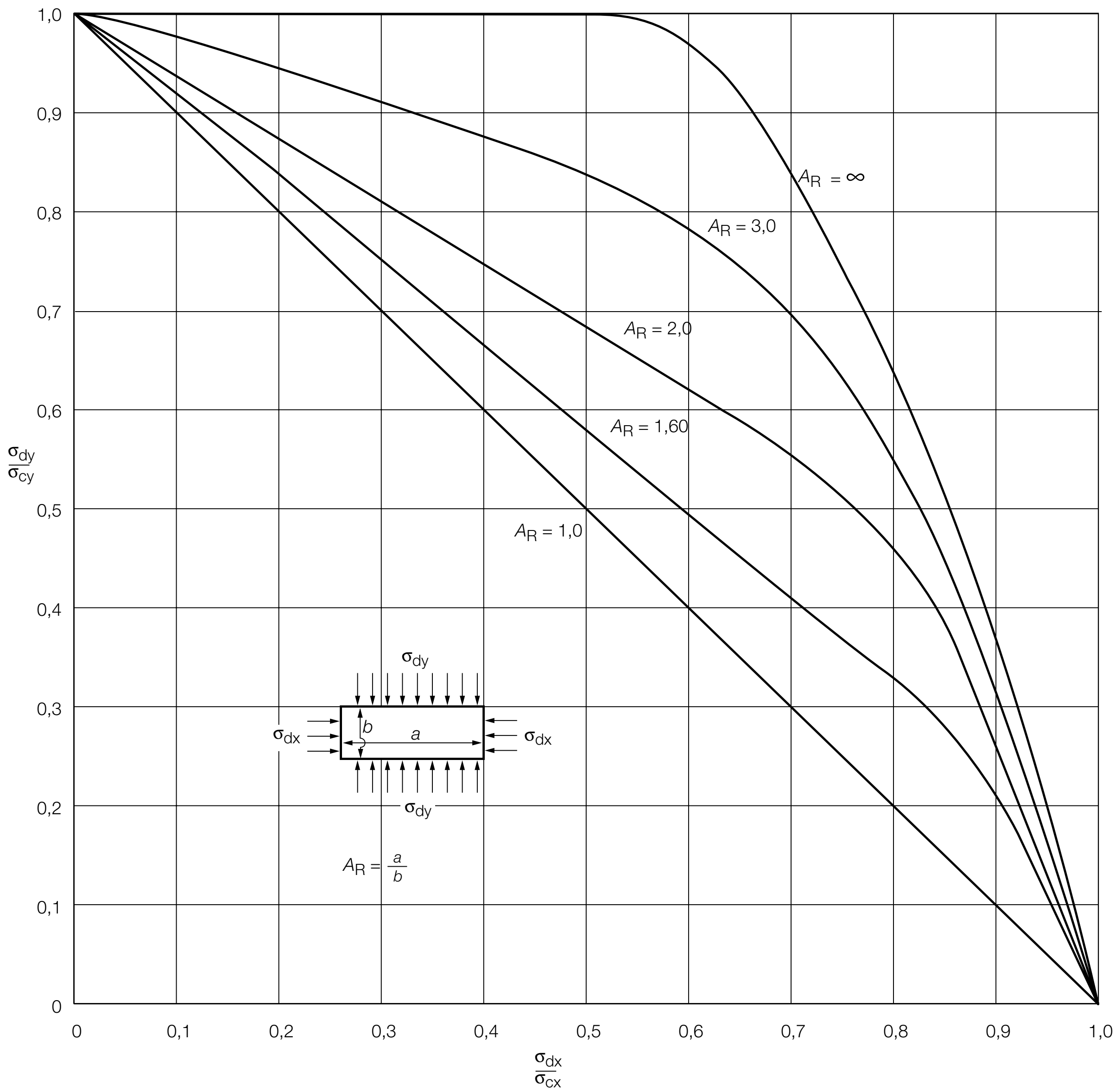


Fig. 2.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 2.4.2(c)

Table 2.4.3 Buckling stress of secondary stiffeners

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \dfrac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \dfrac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385 E \dfrac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\dfrac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 3{,}8\, E \left(\dfrac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

NOTE
The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 2.2.1
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 2.2.1
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end pinned and the other end fixed
= 4 where both ends are fixed
E = Youngs Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}
t_p and σ_o given in 1.3.1
A_{te} and b_{eb} are given in 4.2.1.

Table 2.4.3 Buckling stress of secondary stiffeners (*conclusion*)

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w\, t_w^3}{3}\, 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3\left(1 - \dfrac{0{,}63\, t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3\, t_w}{3}\, 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \dfrac{d_w^3\, t_w^3}{36}\, 10^{-6}$ for flat bars

$= \dfrac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\,(t_f\,(b_f^2 + 2b_f\, d_w + 4d_w^2) + 3t_w\, b_f\, d_w)\, 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \dfrac{k_p\, E t_p^3}{3b\left(1 + \dfrac{1{,}33 k_p\, d_w\, t_p^3}{b t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \dfrac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 2.4.1

m is determined as follows; e.g.. $m = 2$ for $K = 25$

K range	$0 \le K < 4$	$4 \le K < 36$	$36 \le K < 144$	$144 \le K < 400$	$400 \le K < 900$	$900 \le K < 1764$	$(m-1)^2\, m^2 \le K < m^2\,(m+1)^2$
m	1	2	3	4	5	6	*m*

$K = \dfrac{1{,}03 C S^4}{E\, I_w}\, 10^4$

σ_d is the design stress, in N/mm^2
all other symbols as defined in 4.2.1 or 1.3.1

■ Section 5 Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances, finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of an homogeneous clamped plate in air is given by the following:

$$f_{air} = 5537 \frac{t_p}{ls} \sqrt{\left(\frac{1000l}{s}\right)^2 + \left(\frac{s}{1000l}\right)^2 + 0{,}6045} \quad \text{Hz}$$

where

l = panel length, in metres
s = panel breadth, in mm
t_p = panel thickness, in mm.

5.4 Natural frequency of plate and stiffener combination

5.4.1 The natural frequency of a plate stiffener of constant cross section in air is given by the following:

$$f_{air} = \frac{k_i}{20\pi\, l_b^2} \sqrt{\frac{EI}{m\left(1 + \dfrac{\pi^2 EI}{10^4\, l_b^2\, GA}\right)}} \quad \text{Hz}$$

where

l_b = length of stiffener, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 2.5.1
G = shear modulus of elasticity, in N/mm^2
A = shear area of stiffener, in cm^2
I = Inertia of stiffener, in cm^4
E = modulus of elasticity, in N/mm^2.

Table 2.5.1 First mode of vibration constant K_i

End condition	Mode				
	1	2	3	4	5
Simply supported	9,92	—	—	—	—
Fixed ends	22,40	61,70	121,0	200,0	299,0
Simple and fixed	15,4	—	—	—	—

5.5 Effect of submergence

5.5.1 To obtain the frequency f_{water} of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air f_{air} may be modified by the following formula:

$$f_{water} = f_{air} \sqrt{\frac{\kappa_p}{\kappa_p + \dfrac{\rho_l}{\rho_p}}}$$

where

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi\, t_p}{l\, s} \sqrt{\frac{s^2}{10^6} + l^2}$$

where l, s and t_p are as defined in 5.3.1.

Section 6
Dynamic loading

6.1 General

6.1.1 The following formulae are to be used to determine the dynamic response of plate and plate stiffener combinations. The natural frequency of structural items can be determined from Section 5 and the period T may then be determined as follows:

$$T = \frac{1}{f} \text{ seconds}$$

where

f = the natural frequency and is normally to be taken as f_{air}, *see* 5.3.1 for plating or 5.4.1 for plate and stiffener combination.

6.1.2 For bottom impact pressure loads and bow flare and above waterline impact pressure loads required by Ch 3,14 and 15 respectively, the impact pressure is assumed to be represented by a triangular pulse load. The rise time, t_1, for these impact pressures is given in Pt 5, Ch 3,4.2.2 for bottom impact and Pt 5, Ch 3,4.3.2 for bow flare impact.

6.2 Gradually applied load

6.2.1 For a gradually applied load as shown in Fig. 2.6.1 the maximum dynamic load factor f_{DLF} can be calculated as from Table 2.6.1. Linear interpolation may be performed to obtain f_{DLF} values for intermediate t_1/T values.

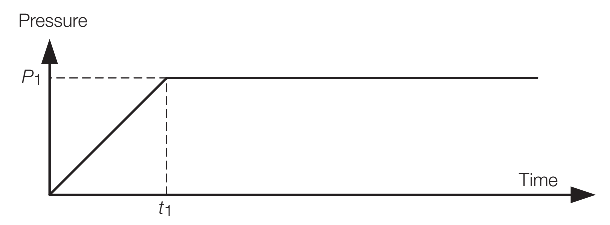


Fig. 2.6.1 Gradually applied load

6.2.2 The time to maximum response can be calculated from Table 2.6.1 with intermediate values determined by linear interpolation.

6.3 Instantaneous load

6.3.1 For an instantaneous applied load as shown in Fig. 2.6.2 the maximum dynamic load factor f_{DLF} can be calculated as from Table 2.6.1. Linear interpolation may be performed to obtain f_{DLF} values for intermediate t_1/T values. The t_1 time value is given in the same section that the impulsive pressure load is specified.

Fig. 2.6.2 Instantaneous pulse load

6.3.2 The time to maximum response can be calculated from Table 2.6.1 with intermediate values determined by linear interpolation.

6.4 Triangular pulse load

6.4.1 For a triangular pulse load as shown in Fig. 2.6.3, the maximum dynamic load factor DLF can be calculated from Table 2.6.1. Linear interpolation may be performed to obtain DLF values for intermediate t_1/T values. The t_1 time value is given in the same section that the impulsive pressure load is specified.

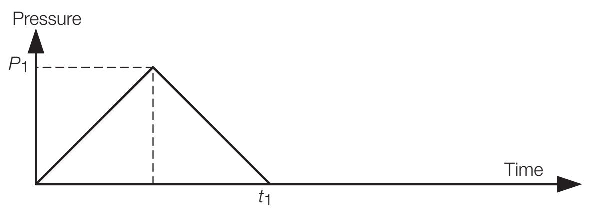


Fig. 2.6.3 Triangular pulse load

6.4.2 The time to maximum response can be calculated from Table 2.6.1 with intermediate values determined by linear interpolation.

Table 2.6.1 Tabulated dynamic load factors

	Dynamic load factor			Time to maximum displacement		
t_1/T	Gradual f_{DLF}	Triangular f_{DLF}	Instant f_{DLF}	Gradual t_m/t_1	Triangular $t_m/2t_1$	Instant t_m/T
0,0	2,0	0,0	0,0			
0,1	1,984	0,312	0,300	5,800	2,484	0,284
0,2	1,935	0,608	0,600	3,000	1,700	0,316
0,3	1,858	0,875	0,850	2,100	1,361	0,348
0,4	1,757	1,098	1,050	1,700	1,163	0,381
0,5	1,637	1,273	1,200	1,450	1,029	0,400
0,6	1,504	1,391	1,300	1,280	0,931	0,415
0,7	1,363	1,465	1,400	1,150	0,856	0,430
0,8	1,232	1,501	1,480	1,080	0,795	0,440
0,9	1,109	1,514	1,530	1,010	0,746	0,445
1,0	1,000	1,508	1,600	1,000	0,704	0,450
				1,500 (1)		
1,1	1,089	1,481	1,630	1,430	0,668	0,453
1,2	1,156	1,441	1,660	1,360	0,637	0,456
1,3	1,198	1,397	1,690	1,290	0,609	0,459
1,4	1,216	1,342	1,715	1,220	0,585	0,462
1,5	1,212	1,282	1,725	1,150	0,563	0,465
1,6	1,189	1,228	1,730	1,119	0,544	0,466
1,7	1,151	1,165	1,730	1,089	0,526	0,468
1,8	1,104	1,104	1,745	1,059	0,510	0,469
1,9	1,052	1,052	1,748	1,029	0,495	0,471
2,0	1,000	1,000	1,750	1,200	0,481	0,473
2,1	1,047	0,960	1,756	1,170	0,520	0,474
2,2	1,085	0,953	1,763	1,140	0,540	0,475
2,3	1,111	0,980	1,769	1,110	0,560	0,477
2,4	1,125	1,016	1,775	1,080	0,580	0,478
2,5	1,127	1,055	1,781	1,050	0,600	0,480
2,6	1,116	1,089	1,786	1,039	0,590	0,480
2,7	1,095	1,115	1,79	1,029	0,580	0,480
2,8	1,067	1,126	1,797	1,019	0,570	0,481
2,9	1,034	1,135	1,802	1,009	0,560	0,481
3,0	1,000	1,158	1,800	1,100	0,550	0,482
3,1	1,032	1,168	1,800	1,089	0,545	0,482
3,2	1,059	1,167	1,808		0,540	0,483
3,3	1,078	1,155	1,812		0,535	0,483
3,4	1,089	1,132	1,817		0,530	0,484
3,5	1,091	1,103	1,821		0,525	0,484
3,6	1,084	1,084	1,825		0,520	0,485
3,7	1,070	1,070	1,829		0,515	0,485
3,8	1,059	1,060	1,833		0,510	0,486
3,9	1,025	1,025	1,837		0,505	0,486
4,0	1,000	1,000	1,825		0,500	0,487
4,1	1,024	0,978	1,828		0,505	0,487
4,2	1,045	0,976	1,831		0,510	0,487
4,3	1,060	0,989	1,835		0,515	0,487
4,4	1,069	1,007	1,838		0,520	0,488
4,5	1,071	1,029	1,842		0,525	0,488
4,6	1,066	1,050	1,845		0,530	0,488
4,7	1,055	1,069	1,849		0,535	0,489
4,8	1,039	1,083	1,852		0,540	0,489
4,9	1,020	1,091	1,855		0,545	0,489
5,0	1,000	1,092	1,850		0,550	0,490
5,1	1,019	1,083	1,853		0,545	0,490
5,2	1,036	1,069	1,856		0,540	0,490
5,3	1,049	1,050	1,859		0,535	0,490
5,4	1,056	1,056	1,862		0,530	0,490
5,5	1,058	1,058	1,865		0,525	0,490
5,6	1,054	1,054	1,868		0,520	0,490
5,7	1,045	1,045	1,870		0,515	0,490
5,8	1,032	1,032	1,873		0,510	0,490
5,9	1,017	1,017	1,876		0,505	0,490
6,0	1,002	1,002	1,870		0,500	0,491

NOTE
The time to maximum displacement curve for a gradually applied load has a step at t_1/T = 1,0.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to monohull craft of steel construction as defined in Pt 1, Ch 2,2.

1.1.2 All NS1, NS2 and NS3 ships as defined in Pt 1 are to comply with the minimum requirements of Section 2 and general structural requirements of Sections 5 to 15.

1.1.3 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3 and supported where necessary by direct calculations.

1.1.4 The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4 and supported by direct calculations where necessary.

1.2 General

1.2.1 The formulae used in this Chapter are to be used in conjunction with the design loadings from Part 5 and design tools in Chapter 2 to determine the rule scantling requirements.

1.2.2 All references to longitudinal locations in the rules are to be taken as forward of the aft end of L_R unless otherwise stated, e.g. 0,75L_R is 75 per cent of L_R forward of the aft end of L_R
where

L_R is defined in Pt 3, Ch 1,5.2.

1.3 Direct calculations

1.3.1 The extent of direct calculation required will depend on the ship structural configuration and operational requirements and is to be agreed between the designer, Owner and Lloyd's Register (hereinafter referred to as 'LR') at an early stage in the plan approval process.

1.3.2 In addition, where the ship is of unusual design, form, proportion or has operational requirements such as very high speed, the scantlings will be specially considered and may require direct calculation.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by rule requirements in accordance with Pt 3, Ch 1,2 and 3.

■ *Section 2* Minimum structural requirements

2.1 General

2.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

2.1.2 The scantlings of plating and stiffeners determined from the Rule scantling requirements are not to be less than that given in Table 3.2.1 for the ship type. Due consideration is to be given to the vessel type correction factor, ω, as defined in Table 3.2.2.

2.1.3 In addition, where plating contributes to the global strength of the ship, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 4.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered. Requirements for corrosion margin are given in Pt 6, Ch 6,2.10.

Table 3.2.1 Minimum structural requirements (*see continuation*)

Item	Minimum scantling		
Shell envelope			
Bottom shell and bilge plating	$\sqrt{k_{ms}}\ (0{,}4\sqrt{L_R}+2)$ mm	$\geq 5{,}0\omega$	
Side shell plating	$\sqrt{k_{ms}}\ (0{,}38\sqrt{L_R}+1{,}2)$ mm	$\geq 4{,}0\omega$	
Breadth of keel plate, if fitted	$7L_R + 340$ mm	≥ 750	*See* Note 1
Keel plate thickness, if fitted	$\omega\sqrt{k_{ms}}\ 1{,}35L_1^{0{,}45}$ mm		*See* Note 2
Breadth of stem plate	$7L_R + 340$ mm	≥ 600	*See* Note 2
Stem plate thickness	$\omega\,(5 + 0{,}083L_2)\sqrt{k_{ms}}$ mm		
Bar keel area, if fitted	$\omega\, k_{ms}\, L_R^{1{,}1}$ cm^2		
Bar keel thickness, if fitted	$\omega\sqrt{k_{ms}}\ (0{,}6L_R + 6)$ mm		*See* Note 2
Single bottom structure			
Centre girder web thickness	$\sqrt{k_{ms}}\ (\sqrt{L_R}+1)$ mm	$\geq 4{,}0\omega$	
Side girder web thickness	$\sqrt{(k_{ms}\, L_R)}$ mm	$\geq 3{,}5\omega$	
Floor web thickness	$\omega\sqrt{k_{ms}}\,(0{,}03L_R + 3{,}5)$ mm	$\geq 3{,}5\omega$	
Centreline girder face flat area	$\omega\, 0{,}5\, L_R\, k_{ms}$ cm^2		
Floor face flat area	$4{,}5\, Tk_{ms}\left(1 - \dfrac{2{,}5}{B}\right)$ cm^2		*See* Note 3
Depth of floors, d_f	$35\,(1{,}6B + T) - 75$ mm		
Double bottom structure			
Inner bottom plating thickness	$\sqrt{k_{ms}}\ (0{,}4\sqrt{L_R}+1{,}5)$ mm	$\geq 4{,}0\omega$	
Centreline girder web thickness	$\sqrt{k_{ms}}\ (0{,}9\sqrt{L_R}+1)$ mm	$\geq 4{,}0\omega$	
Side girder web thickness	$\sqrt{k_{ms}}\ 0{,}72\sqrt{L_R}$ mm	$\geq 3{,}5\omega$	
Floor web thickness	$\sqrt{k_{ms}}\ (0{,}03L_R + 3{,}5)$ mm	$\geq 3{,}5\omega$	
Depth of double bottom, d_{DB}	$28B + 205\sqrt{T}$ mm	≥ 630	
Watertight bulkheads			
Plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R}+1{,}0)$ mm	$\geq 3{,}5\omega$	
Deep tank bulkheads			
Plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2)$ mm	$\geq 4{,}0\omega$	
Deck structure			
Strength deck	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2)$ mm	$\geq 4{,}0\omega$	
Internal and lower decks	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R}+1{,}7)$ mm	$\geq 3{,}0\omega$	
Exposed deck plating thickness, fwd of $0{,}75L_R$	$\omega\sqrt{k_{ms}}\,(0{,}015\, L_R + 5{,}5)$ mm	$\geq 5{,}0\omega$	
Exposed deck plating thickness, aft of $0{,}75L_R$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2)$ mm	$\geq 4{,}0\omega$	

Table 3.2.1 Minimum structural requirements (*conclusion*)

Item	Minimum scantling	
Superstructure and deckhouses		
Deck plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R} + 1{,}7)$ mm	$\geq 3{,}0\omega$
Side plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R} + 1)$ mm	$\geq 3{,}0\omega$
Front plating thickness, fwd of $0{,}75L_R$	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R} + 2)$ mm	$\geq 5{,}0\omega$
Front plating thickness, aft of $0{,}75L_R$	$\omega\sqrt{k_{ms}}\,(0{,}25\sqrt{L_R} + 2)$ mm	$\geq 4{,}0\omega$
Back plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}25\sqrt{L_R} + 2)$ mm	$\geq 3{,}0\omega$
Machinery casing plating thickness	$\omega\sqrt{k_{ms}}\,(0{,}25\sqrt{L_R} + 2)$ mm	$\geq 3{,}0\omega$
Pillars		
Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\;0{,}05d_p$ mm	$\geq 2{,}5\omega$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\;0{,}05b_p$ mm	$\geq 2{,}5\omega$
Plated mast structures which are not structurally effective		
Deck, side and back plating	3 mm	
Front plating thickness, fwd of $0{,}75L_R$	5 mm	
Front plating thickness, aft of $0{,}75L_R$	4 mm	

Symbols

L_1 = L_R but need not be taken greater than 190 m
L_2 = L_R but need not be taken greater than 215 m
ω = vessel type correction factor as determined from Table 3.2.2
k_{ms} = $635/(\sigma_o + \sigma_u)$
σ_o = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R, B and T are defined in Pt 3, Ch 1,5.2

NOTES
1. Maximum keel breadth 1800 mm.
2. Not to be less than adjacent shell plate. Above the design waterline the bar keel may be the same as the adjacent shell.
3. Face plate thickness not to be less than floor thickness.

Table 3.2.2 Vessel type correction factor (ω)

Vessel type	ω
Bottom structure of ships operating aground	1,2
NS1	1,1
NS2 and 3	1,0

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. For example decks in workshops. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion from, i.e. removal or stores routes, working areas, forefoot region, etc., are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the ship. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.4.3 When decks that are not structurally effective or subject to significant inplane stresses are fitted with approved sheathing, the thickness derived may be reduced by 10 per cent for a 50 mm sheathing thickness, or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. Inside deckhouses the thickness may be reduced by a further 10 per cent.

2.5 Special considerations

2.5.1 Flight decks and structures in way of launcher ramps, gun platforms, etc., will be subject to special consideration.

2.5.2 The minimum plating thickness of ships intended for operation in ice conditions will be specially considered.

2.5.3 Ships with shock enhanced notation are not to be fitted with bar keels. Docking arrangements are to be specially considered.

2.5.4 For large or novel ships, the scantlings of the stem will be specially considered.

2.5.5 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

2.6 Direct calculations

2.6.1 The thickness requirements derived from Table 3.2.1 may be specially considered, where direct calculation procedures are adopted to demonstrate the suitability of the proposed alternative, e.g. shear buckling analysis may be performed on girder or floor webs.

■ *Section 3* NS1 scantling determination

3.1 General

3.1.1 The scantlings for NS1 ships may be determined from the global and local requirements defined in this Section. In addition the general requirements of Sections 5 to 15 are to be complied with.

3.1.2 The scantlings given in this Section are based in the assumption that there is negligible loss in strength by corrosion.

3.1.3 The corrosion margins specified in Ch 6,2.10 are to be applied to the derived scantlings as appropriate, *see also* Ch 1,2.2.1.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

F_B = local scantling reduction factor for hull members below the neutral axis, *see* 3.6

F_D = local scantling reduction factor for hull members above the neutral axis, *see* 3.6

I_{min} = minimum moment of inertia, of the hull midship section about the transverse neutral axis, in m^4

Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, *see* Ch 4,2

Z_{min} = minimum hull midship section modulus about the transverse neutral axis, in m^3

σ_p = permissible combined stress (still water plus wave), in N/mm^2, *see* Ch 4,2

σ_o = yield strength of material in N/mm^2

σ_D, σ_B = maximum hull vertical bending stress at strength deck and keel respectively, in N/mm^2 determined from Ch 4,2

k_L = longitudinal high strength steel factor, *see* Ch 5,2.1.2

k_s = the local high strength steel factor, *see* Ch 5,2.1.1

L_1 = L_R but need not be taken greater than 190 m

L_2 = L_R but need not be greater than 215 m

s = spacing of secondary stiffeners, in mm

S = spacing of primary members, in metres

ρ = relative density (specific gravity) of a liquid carried in a tank not to be taken less than 1,025

f = $\dfrac{1}{1+\left(\dfrac{s}{1000S}\right)^2}$ transverse framing aspect ratio correction

L_R is as defined in Pt 3, Ch 1,5.2.

3.3 Hull girder strength

3.3.1 For all ships, the hull girder strength requirements of Ch 4,2 are to be complied with.

3.3.2 As required by Ch 4,2, the hull girder bending and shear stresses for all longitudinally effective material is to be verified against the permissible stresses and the buckling requirements of Ch 2,4. In addition, the lateral and torsional stability of all effective longitudinals together with the web and flange buckling criteria are to be verified in accordance with Ch 2,4.

3.3.3 In addition, the minimum requirements of 3.4 and 3.5 are to be satisfied.

3.4 Minimum hull section modulus

3.4.1 The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = 0{,}95 k_L M_o \times 10^{-5} \quad m^3$$

where

M_o is given in Pt 5, Ch 4,3.3.1

K_L is as defined in 3.2.1.

3.5 Minimum hull moment of inertia

3.5.1 The hull midship section moment of inertia about the transverse neutral axis is to be not less than the following using the maximum total bending moment, sagging or hogging:

$I_{min} = 3{,}0 L_R M_R / 175 \times 10^{-5}$ m^4

where

M_R = design bending moment, sagging (negative) and hogging (positive), in kN m, to be taken negative or positive according to the convention given in Pt 5, Ch 4,3.10.

3.6 Local reduction factors

3.6.1 Where the maximum hull vertical bending stress at deck or keel is less than the permissible combined stress, σ_p, reductions in local scantlings within $0{,}3L_R$ to $0{,}7L_R$ may be permitted. The reduction factors are defined as follows:

For hull members above the neutral axis

$F_D = \sigma_D/\sigma_p$

For hull members below the neutral axis

$F_B = \sigma_B/\sigma_p$

In general the values of σ_D and σ_B to be used are the greater of the sagging or hogging stresses, and F_D and F_B are not to be taken less than 0,67 for plating and 0,75 for longitudinal stiffeners. σ_B, σ_D and σ_p are defined in 3.2.1.

3.6.2 Where higher tensile steel is used in the hull structure, the values of F_D and F_B for the mild steel part are to be taken as not less than z/z_M

where

z = vertical distance from the hull transverse neutral axis to the position considered, in metres

z_M = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, above or below the neutral axis as appropriate.

3.7 Taper requirements for hull envelope

3.7.1 The scantlings determined at amidships are to be maintained between $0{,}3L_R$ and $0{,}7L_R$. Outside of this region and forward of $0{,}075L_R$ and aft of $0{,}925L_R$ the scantling requirements for the following structural items are to be determined by linear interpolation between the midship section and the forward or after ends as appropriate, *see* Fig. 3.3.1.

- Strength deck plating.
- Deck longitudinals.
- Shell envelope.

3.7.2 The taper requirement does not apply to ships where there are large openings in the decks such that the torsional rigidity of the hull is significantly reduced.

3.7.3 The thickness may need to be increased above the taper thickness by military features, special features or other requirements such as bottom slamming or bow flare impact.

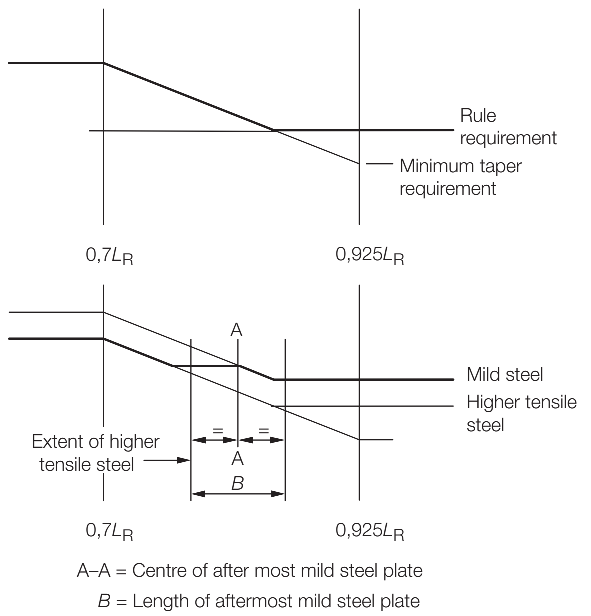


Fig. 3.3.1 Taper requirements

3.7.4 The formulae for the taper values are based on the assumption that the yield values of steel is the same at amidships and ends. Where higher tensile steel is used in the midship region and mild steel at the ends, the taper values should be calculated for both yield values of steel. In way of the transition from higher tensile to mild steel, the thickness may be determined in accordance with Fig. 3.3.1. The aft end thickness is to be tapered in a similar manner.

3.7.5 Where the higher tensile steel longitudinals extend beyond the point of transition from higher tensile to mild steel plating, the modulus of the composite section is to be greater than the required mild steel value at the deck plate flange, and k_L times the mild steel value at the higher tensile flange.

3.8 Grouped stiffeners

3.8.1 Where stiffeners are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of the following:

(a) the mean value of the section modulus required for individual stiffeners within the group;
(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

3.9 Shell envelope plating

3.9.1 Shell envelope plating for both longitudinally and transversely framed ships is to comply with the requirements of Table 3.3.1.

3.9.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

Table 3.3.1 Shell envelope plating (*see continuation*)

<table>
<tr><th rowspan="2">Location</th><th colspan="2">Minimum thickness, in mm, see also 5.3.1</th></tr>
<tr><th>Longitudinal framing</th><th>Transverse framing</th></tr>
<tr><td>(1) Bottom plating and bilge where framed $0{,}3L_R$ to $0{,}7L_R$
(See Notes 3, 4 and 5)</td><td>The greater of the following:
(a) $t = 9{,}0 s_1 (0{,}043 L_1 + 10) \sqrt{\frac{F_B}{k_L}} \times 10^{-4}$
(b) $t = 4{,}7 s_1 \sqrt{\frac{h_{T2}\, k_s}{1{,}8 - F_B}} \times 10^{-3}$</td><td>The greater of the following:
(a) $t = 0{,}001 s_1 f (0{,}056 L_1 + 16{,}7) \sqrt{\frac{F_B}{k_L}}$
(see Note 4)
(b) $t = 5{,}7 s_1 \sqrt{\frac{h_{T2}\, k_s}{1{,}8 - F_B}} \times 10^{-3}$</td></tr>
<tr><td>(2) Bottom plating and bilge fwd of $0{,}925L_R$ (see Note 2) aft of $0{,}075L_R$</td><td colspan="2">$t = (6{,}0 + 0{,}03 L_R) \sqrt{\frac{k_s\, s_1}{s_b}}$</td></tr>
<tr><td rowspan="3">(3) Side shell clear of sheerstrake $0{,}3L_R$ to $0{,}7L_R$
(see Notes 1 and 5)</td><td>(a) Above $\frac{D}{2}$ from base:
The greater of the following:
(i) $t = 9{,}0 s_1 (0{,}059 L_1 + 7) \sqrt{\frac{F_D}{k_L}} \times 10^{-4}$
(ii) $t = 3{,}8 s_1 \sqrt{h_{T1}\, k_s} \times 10^{-3}$</td><td>(a) Within $\frac{D}{4}$ from the gunwale:
The greater of the following:
(i) $t = 0{,}00085 s_1 f (0{,}083 L_1 + 10) \sqrt{\frac{F_D}{k_L}}$
(ii) $t = 3{,}8 s_1 \sqrt{h_{T1}\, k_s} \times 10^{-3}$</td></tr>
<tr><td>(b) At upper turn of bilge:
The greater of the following:
(i) $t = 9{,}0 s_1 (0{,}059 L_1 + 7) \sqrt{\frac{F_B}{k_L}} \times 10^{-4}$
(ii) $t = 4{,}9 s_1 \sqrt{\frac{h_{T2}\, k_s}{2 - F_B}} \times 10^{-3}$</td><td>(b) Within $\frac{D}{4}$ from mid-depth:
The greater of the following:
(i) $t = 9{,}0 s_1 (0{,}059 L_1 + 7) \sqrt{\frac{F_M}{k_L}} \times 10^{-4}$
(ii) $t = 4{,}6 s_1 \sqrt{h_{T1}\, k_s} \times 10^{-3}$</td></tr>
<tr><td>(c) Between upper turn of bilge and $\frac{D}{2}$ from base:
The greater of the following:
(i) t from (b)(i)
(ii) t from interpolation between (a)(ii) and (b)(ii)</td><td>(c) Within $\frac{D}{4}$ from base (excluding bilge plating)
see Note 1
The greater of the following:
(i) $t = 0{,}00085 s_1 f (0{,}083 L_1 + 10) \sqrt{\frac{F_B}{k_L}}$
(ii) $t = 5{,}7 s_1 \sqrt{\frac{h_{T2}\, k_s}{1{,}8 - F_B}} \times 10^{-3}$</td></tr>
<tr><td>(4) Side shell fwd of $0{,}925L_R$ aft of $0{,}075L_R$</td><td colspan="2">$t = (6{,}0 + 0{,}03 L_R) \sqrt{\frac{k_s\, s_1}{s_b}}$</td></tr>
<tr><td>(5) Sheerstrake</td><td colspan="2">$0{,}00075 s_1 \sqrt{L_R\, k_s} + 1{,}5$
but not less than the thickness of the adjacent side plating.</td></tr>
</table>

3.9.3 Additional requirements for shell envelope plating are indicated in Section 5.

3.10 Shell envelope framing

3.10.1 Shell envelope framing for both longitudinally and transversely framed ships is to comply with the requirements of Table 3.3.2 and Table 3.3.3.

Table 3.3.1 Shell envelope plating (*conclusion*)

Symbols	
F_B, F_D are as defined in 3.6 L_R, D, T, as defined in Pt 3, Ch1,5.2 L_1, L_2, ρ, s, S, f, k_L, k_s are as defined in 3.2.1 C_{WL}= a wave head in metres = $0{,}0771 L_R \, e^{-0{,}0044 L_R}$ Where L_R > 227 m, C_{WL} is not to be taken less than 6,446 m h_{T1} = $T + C_{WL}$ m but need not be taken greater than 1,36T m h_{T2} = (T + 0,5 C_{WL}), in metres but need not be taken greater than 1,2T m	s_1 = s, but is not to be taken less than s_b s_b = 600mm fwd of 0,95L_R = 700mm 0,95L_R to 0,7L_R = 700mm 0,7L_R to 0,05L_R = 600mm aft of 0,05L_R F_M = the greater of F_B and F_D e = base of natural logarithms, 2,7183

NOTES
1. Outside the vertical extent of higher tensile steel as defined in Ch 2,1.6.3 the value of k_L may be taken as 1,0.
2. *See also* Sections 14 and 15 for requirements for bottom slamming and bow flare impact.
3. For keel plate thickness and breadth *see* Table 3.2.1.
4. Unframed bilge plating will be specially considered.
5. Shell envelope plating from 0,075L_R to 0,3L_R and 0,7L_R to 0,925L_R is to be determined by assuming a linear taper from the midship value given by (1) or (3) as appropriate to $t = (6{,}0 + 0{,}03L_R)\sqrt{k_s}$ at 0,075L_R and 0,925L_R. The plating thickness determined is not to be less than the value given by (2) or (4) as appropriate. *See also* 3.7.

3.10.2 Shell envelope primary structure for both longitudinally and transversely framed ships is to comply with the requirements of Table 3.3.4.

3.10.3 Additional requirements for shell envelope framing are indicated in Section 6.

3.11 Watertight bulkheads and deep tanks

3.11.1 Watertight bulkhead and deep tank scantlings are to comply with the requirements of Table 3.3.5. Factors for the stiffener end connection type are given in Fig. 3.3.3.

3.11.2 The thickness of the watertight bulkhead and deep tank plating is in no case to be less than the appropriate minimum requirements given in Section 2.

3.11.3 Additional requirements for watertight bulkhead and deep tank scantlings are indicated in Pt 3, Ch 2,4 and Pt 3, Ch 2,3 respectively.

3.12 Deck structures

3.12.1 Deck plating for both longitudinally and transversely framed ships is to comply with the requirements of Table 3.3.6.

3.12.2 Deck framing for both longitudinally and transversely framed ships is to comply with the requirements of Table 3.3.7 and for transversely framed ships Table 3.3.8.

3.12.3 Deck primary structure for both longitudinally and transversely framed ships is to comply with the following requirements:

(1) Girders and transverses or deep beams in way of dry spaces:
   (a) supporting up to three point loads Z to be determined using calculations based on a stress of 123,5/k_s N/mm^2, assuming fixed ends and the inertia given as follows:
   $$I = \frac{1{,}85}{k_s} l_e Z \text{ cm}^4$$
   (b) supporting four or more point loads or a uniformly distributed load
   $$Z = 4{,}75 k_s S H_g l_e^2 \text{ cm}^3$$
   $$I = \frac{1{,}85}{k_s} l_e Z \text{ cm}^4$$

(2) Girders and transverses in way of the crown or bottom of a tank
   $$Z = 11{,}7 k_s h_4 S l_e^2 \text{ cm}^3$$
   $$I = \frac{2{,}8}{k_s} l_e Z \text{ cm}^4$$

where
H_g = weather head h_1, or deck pressure head h_2, in metres as given in Table 3.3.7
h_4 = tank head, in metres
l_e = effective span length in metres as defined in Ch 2,2.6
S, k_s are as defined in 3.2.1.

3.12.4 The thickness of the deck plating is in no case to be less than the appropriate minimum requirements given in Section 2.

3.12.5 Additional requirements for deck structures are indicated in Section 10.

Table 3.3.2 Shell envelope framing ($0,2L_R$ to $0,8L_R$)

Longitudinal framing	Modulus, in cm^3
(1) Side longitudinals in way of dry spaces, including double skin construction (*see* Note 1)	The lesser of the following: (a) $Z = 0{,}05\ s k_s h_{T1}\ l_e^2\ F_s\ F_1$ (b) Z from (3)(a) evaluated using s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(2) Side longitudinals in way of wet spaces or deep tanks	The greater of the following: (a) Z as from (1) (b) As required by Table 3.3.5 for deep tanks, using h_{T3} instead of h_4, but need not exceed Z from (3)(b) evaluated using l_{e1}, s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(3) Bottom and bilge longitudinals	The greater of the following: (a) $Z = (0{,}002 l_{e1} + 0{,}042)\ s\ k_s\ h_{T2}\ l_e^2\ F_s\ F_1$ (b) $Z = (0{,}002 l_{e1} + 0{,}042)\ s\ k_s\ h_{T3}\ l_e^2\ F_s\ F_1$

Transverse framing	Modulus, in cm^3	Inertia, in cm^4
(4) Side frames in dry spaces	The greater of the following: (a) $Z = C\ s\ k_s\ h_{T1} H^2 \times 10^{-3}$ (b) $Z = 8{,}2 s\ k_s\ D_1 \times 10^{-3}$	$I = \dfrac{3{,}2}{k_s}\ H\ Z$
(5) Side frames in way of wet spaces or deep tanks	The greater of the following: (a) $1{,}15 \times Z$ from (4) (b) $Z = 6 s\ k_s\ h\ H^2 \times 10^{-3}$	$I = \dfrac{3{,}2}{k_s}\ H\ Z$
(6) Frames supporting hatch end beams or deck transverses (*see* Note 3)	The greater of the following: (a) Z from (4) (b) $Z = 2{,}2\ (0{,}2 l_s^2 + H^2)\ k_s\ S\ H_9$	$I = \dfrac{3{,}2}{k_s}\ H\ Z$
(7) Bottom transverse frames (*see* Note 4)	$Z = 2 s\ k_s\ T\ l_e \times 10^{-2}$	—

Symbols

ρ, L_1, L_2, s, k_s, S as defined in 3.2.1

L_R, D, T as defined in Pt 3, Ch 1,5.2

C_{WL} as defined in Table 3.3.1

F_B, F_D as defined in 3.6

l_e = as defined in Ch 2,2.6, but is not to be taken less than 1,5 m except in way of the centre girder brackets required by 8.5.3 where a minimum span of 1,25 m may be used

l_{e1} = l_e in metres, but is not to be taken less than 2,5 m and need not be taken greater than 5,0 m

F_s is a fatigue factor for side longitudinals defined in Table 3.3.3

$C_1 = \dfrac{60}{225 - 165F_D}$ at deck

$= 1{,}0$ at $\dfrac{D}{2}$

$= \dfrac{75}{225 - 150F_B}$ at base line

Intermediate values by interpolation

$F_1 = \dfrac{D\ C_1}{4D + 20h_5}$ for side longitudinals above $\dfrac{D}{2}$

$= \dfrac{D\ C_1}{25D - 20h_5}$ for side longitudinals below $\dfrac{D}{2}$ and bottom longitudinals

minimum $F_1 = 0{,}14$

where

z = height above base, in metres

f_{cw} = 0,5 at base line
= 1,0 at T
= 0 at 1,6T and above
Intermediate values by interpolation

H_9 = weather head, h_1, or stores head, h_2, in metres, as defined in Table 3.3.7, whichever is applicable

D_1 = 1,6T but not less than 10 or greater then 16 (*see* Note 1)

H = vertical framing depth in m, but not less than 2,5 m, *see* Note 2

h_{T1} = $(T - z + f_{cw}\ C_{WL})\ F_\lambda$ below T
= $f_{cw}\ C_{WL}\ F_\lambda$ above T but not less than the greater of $F_\lambda L_1/70$ or 1,2 m

h_{T2} = $(T + 0{,}5C_{WL})\ F_\lambda$

h_{T1} and h_{T2} need not exceed $(1{,}6T - z + D_1/8)$ below 1,6T and $(z - 1{,}6T + D_1/8)$ above 1,6T

h_{T3} = $0{,}9h_4 - 0{,}25T$, in metres, at the base line
= $0{,}9h_4$, in metres, at and above $T/4$ from the base line, intermediate values by linear interpolation

h_4 = load head required by Table 3.3.5 for deep tanks

h_5 = measured from the mid length of the stiffener to the strength deck at side

h = h_4 or h_5 whichever is greater

F_λ = 1,0 for $L_R \leq 200$ m
= $[1{,}0 + 0{,}0023(L_R - 200)]$ for $L_R > 200$ m

C = end connection factor
= 3,1 where two Rule standard brackets are fitted
= $3{,}1\ (1{,}8 - 0{,}8 l_a/l_b)$ where one Rule standard bracket and one reduced bracket fitted
= $3{,}1\ (2{,}15 - 1{,}15 l_{am}/l_b)$ where two reduced brackets are fitted
= 5,5 where one Rule standard bracket is fitted
= $5{,}5\ (1{,}2 - 0{,}2 l_a/l_b)$ where one reduced bracket is fitted
= 6,4 where no bracket is fitted
The requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l_a = equivalent arm length, in mm, as derived from Pt 6, Ch 2,3.2.5.

l_b = as defined in Ch 2,3.2.5

l_{am} = mean equivalent arm length, in mm, for both brackets

l_s = span of supported beam or transverse in metres

NOTES

1. The scantlings of members above $D/2$ may require special consideration on the basis of structural configuration and the distribution of bending stress at the section concerned.
2. Where frames are inclined at more than 15° to the vertical, H, is to be measured along a chord between span points of the frame.
3. If the modulus obtained from (6) for frames under deck transverses exceeds that obtained from (4) and (5), the intermediate frames may be reduced provided that the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is to be not less than that given by (4)(b).
4. For single bottom structure a plate floor is to be fitted at every frame.

Table 3.3.3 Shell envelope framing forward and aft

Location	Modulus, in cm^3	
Longitudinal framing		
(1) Side longitudinals in way of dry spaces including double skin construction (*see* Note 3): (a) Forward of the collision bulkhead (b) Aft of the aft peak bulkhead (c) Between the collision bulkhead and 0,8L and between aft peak bulkhead and 0,2L	$Z = 0{,}0065s\ k_s\, h_{T1}\, l_e^2\, F_s$ but not less than $Z = 0{,}007s\ k_s\, l_e^2\ (0{,}6 + 0{,}167D_2)$ $Z = 0{,}008s\ k_s\, h_{T1}\, l_e^2\, F_s$ but not less than $Z = 0{,}007s\ k_s\, l_e^2\ (0{,}6 + 0{,}167D_2)$ $Z = 0{,}0065s\ k_s\, h_{T1}\, l_e^2\, F_s$ or as required in the midship region whichever is the greater, but not less than $Z = 0{,}007s\ k_s\, l_e^2\ (0{,}6 + 0{,}167D_2)$	
(2) Side longitudinals in way of double skin or deep tanks	As required in the midship region	
(3) Bottom and bilge longitudinals (*see* Note 4)	As required in the midship region	
Transverse framing	Inertia. cm^4	
(4) Side frames fwd of collision bulkhead and aft of aft peak bulkhead	The greater of (a) $Z = 1{,}85s\ k_s\ T\ D_2\ S_1 \times 10^{-3}$ (b) $Z = 0{,}007s\ k_s\ l_e^2\ (0{,}6 + 0{,}167D_2)$	$I = f_1\ S_1\ Z/k_s$
(5) All other frames in dry spaces forward of 0,8L and aft 0,2L (*see* Note 2)	The greater of the following (a) $Z = C\ s\ k_s\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 8{,}2s\ k_s\ D_2 \times 10^{-3}$ (c) $Z = 0{,}007s\ k_s\ l_e^2\ (0{,}6 + 0{,}167D_2)$	$I = f_1\ S_1\ Z/k_s$
(6) Panting stringer	Web depth, d_w, same depth as frames Web thickness, $t = 5 + 0{,}025L_2$ mm Face area, $A = k_s\ S_2\ (H + 1)$ cm^2	
(7) Main and 'tween deck frames elsewhere	As required in the midship region	

Symbols

L_1, L_2, s, k_s as defined in 3.2.1
L_R, D, T as defined in Pt 3, Ch 1,5.2
C_{WL} as defined in Table 3.3.1
F_λ as defined in Table 3.3.2
l_e = as defined in Ch 2,2.6 but is to be taken not less than 1,5 m
D_2 = $T + H_b$ metres, where H_b is the minimum bow height, in metres, obtained from Pt 3, Ch 2,5.3
H = vertical framing depth, in metres, of sideframes, but is to be taken not less than 2,5 m (*see* Note 1)
S_1 = vertical spacing of peak stringers or height of lower deck above the peak, in metres
S_2 = vertical spacing of panting stringers, in metres
C = end connection factor, *see* Table 3.3.2
f_L = 1,32 aft of 0,15L_R
= 1,0 from 0,2L_R to 0,8L_R
= 1,71 fwd of 0,85L_R
Intermediate positions by interpolation
z = height above baseline in metres

h_{T1} = $(T - z + f_L\ f_{cw}\ C_{WL})\ F_\lambda$ below T
= $f_L\ f_{cw}\ C_{WL}$, F_λ above T but not less than $f_L\ F_\lambda\ L_1/70$
f_{cw} = 0,5 at baseline
= 1,0 at 0,65D_2 and above
Intermediate positions by interpolation (*see* Note 6)
f_1 = 3,5 forward and 3,2 aft
F_s = fatigue factor for side longitudinals for built symmetric sections, flat bars, bulbs and T bars
= 1,05 at keel, 1,1 at T, 1,0 at 1,6T and above
for angle bars
= $0{,}5\left(1 + \dfrac{1{,}1}{k_s}\right)$ at keel
= $\dfrac{1{,}1}{k_s}$ at $\dfrac{D}{2}$
= 1,0 at 1,6T and above
built asymmetric sections will be specially considered.
Intermediate values by linear interpolation

NOTES
1. Where frames are inclined at more than 15° to the vertical, H is to be measured along a chord between the span points of the frame.
2. The modulus for these members need not exceed that derived from (4) using H in place of S_1.
3. Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50k per cent from that obtained for locations (2) and (3) as applicable.
4. Shell framing is also to comply with the requirements for bottom slamming and bow flare impact in Section 14 and Section 15 respectively.
5. For ships where $T > 0{,}65D_1$, the distribution of f_{cw} will be specially considered.

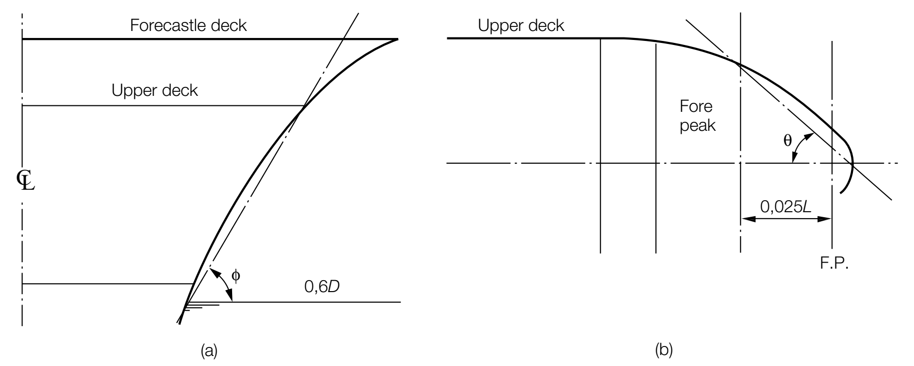
Table 3.3.4 Shell envelope primary structure

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system:		
(1) Side transverse web frames in dry spaces	$Z = 9{,}0 k_s S h_{T1} l_e^2$	—
(2) Side transverse web frames in deep tanks (a) midships (b) aft of $0{,}2L_R$ (c) fwd of $0{,}8L_R$	 $Z = 9{,}4 k_s S h_4 l_e^2$ $Z = 11{,}0 k_s S h_4 l_e^2$ $Z = 11{,}0 k_s S h_4 l_e^2 f_\gamma$ or as (1) above, whichever is the greater	$I = \frac{2{,}5}{k_s} l_e Z$
(3) Side transverses in dry spaces above $1{,}6T$ (*see* Note 2)	$Z = C_2 k_s S T H \sqrt{D}$	—
Transverse framing system:		
(4) Side stringers in dry spaces	$Z = 7{,}0 k_s S h_{T1} l_e^2$	—
(5) Side stringers in deep tanks	$Z = 9{,}4 k_s S h_4 l_e^2$ or as (4) above, whichever is the greater	$I = \frac{2{,}5}{k_s} l_e Z$
(6) Web frames in dry spaces above $1{,}6T$ (*see* Note 2)	$Z = C_3 k_s S T H \sqrt{D}$	—
(7) Web frames supporting side stringers	Z determined from calculation based on following assumptions: (a) fixed ends (b) point loadings (c) head $f_\gamma h_4$ or $f_\gamma h_{T1}$ as applicable (d) bending stress $\frac{100}{k_s}$ N/mm^2 (e) shear stress $\frac{90}{k_s}$ N/mm^2	$I = \frac{2{,}5}{k_s} l_e Z$

Symbols

ρ, s, S, k_s, as defined in 3.2.1
D, T, L_R as defined in Pt 3, Ch 1,5.2
h_4 = tank head, in metres, as defined in Table 3.3.6
L = load head, in metres, measured from mid-point of span to upper deck at side amidships
l_e = effective length of stiffening member, in metres, *see* Ch 2,2.6
h_{T1} = as defined in Table 3.3.3
f_γ = measured at midspan of member fwd of $0{,}8L_R$
= 1,0 at base line
= B_f at $0{,}6D$ above base
= $0{,}5\,(B_f - 1) + 1$ at D above base
= 1,0 at any depth aft of $0{,}8L_R$
(intermediate values by linear interpolation)
B_f = *see* Fig. 3.3.2 for frame members fwd of $0{,}8L_R$
= 1 for framing members aft of $0{,}8L_R$
C_2,C_3 = from Fig. 3.3.4
H = vertical height between decks in metres

NOTES
1. For primary structure in way of machinery spaces and also forward of $0{,}8L_R$ the minimum web depth is not to be less than 2,5 times the depth of adjacent frames or longitudinals as appropriate. Stringers forward of $0{,}8L_R$ may be 2,2 times the depth of the adjacent stiffener.
2. For stringers and webs in fore peak tanks or deep tanks, *see* Pt 3, Ch 2,3.8.
3. The breadths and effective length should be measured along the line of the shell.



Conditions for ϕ

1. ϕ to be deduced at $0{,}975L_R$
2. Aft of fore peak tank ϕ is to be deduced at section being considered
3. For ships with a bulbous bow the angle ϕ is to be measured from the narrowest point of the bow between $0{,}6D$ from base and upper deck

Bow fullness factor
$B_f = 2{,}45 \cos\phi \tan\theta$
but not to be taken less than 1,0

Fig. 3.3.2 Bow fullness factor

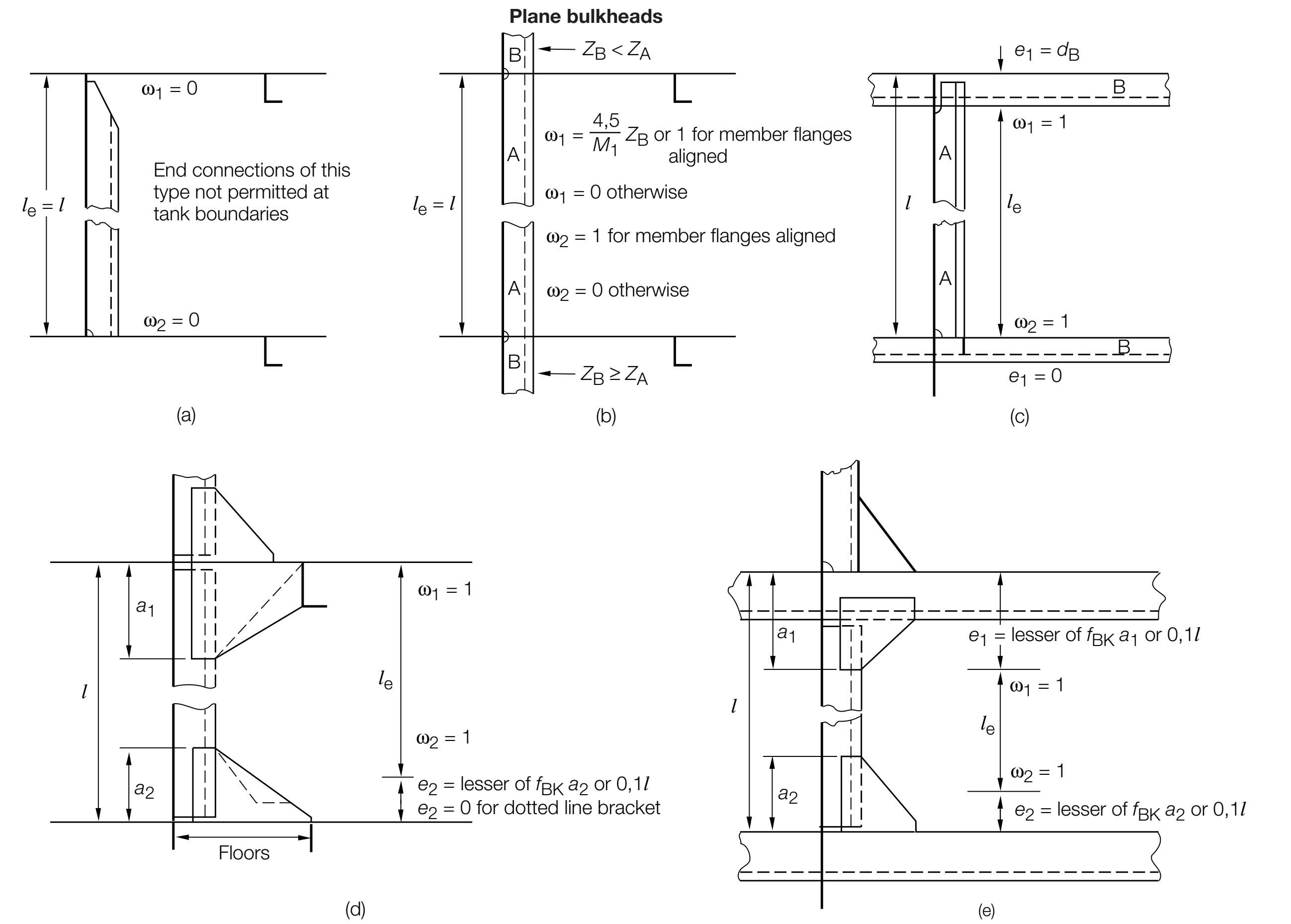
Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings

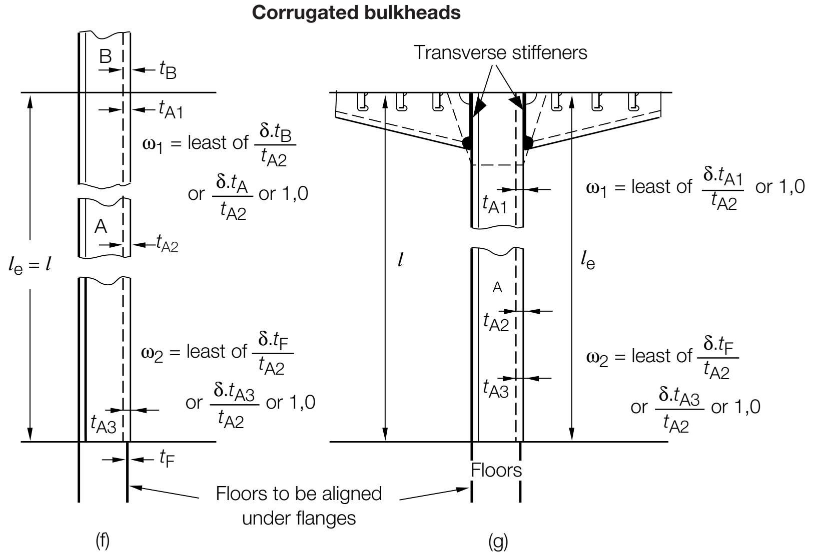
Item and requirement	Watertight bulkheads and decks	Deep tank bulkheads, decks and collision bulkheads
Plating		
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004s\,\beta\sqrt{h_4\,k_s}$ mm but not less than 5,0 mm	$t = 0{,}0057s\,\beta\sqrt{h_4\,k_s}$ mm but not less than 6,0 mm
Secondary stiffening		
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s\,k_s h_4\,l_e^2}{71f_s\,(\omega_1 + \omega_2 + 2)}$ cm^3	$Z = \dfrac{s\,k_s h_4\,l_e^2}{22f_s\,(\omega_1 + \omega_2 + 2)}$ cm^3
(3) Inertia of rolled and built stiffeners and swedges	–	$I = \dfrac{2{,}3}{k_s}\,l_e Z$ cm^4
Primary stiffening		
(4) Stringers or webs supporting vertical or horizontal stiffening: (a) Modulus	$Z = 5{,}0k_s h_4 S\,l_e^2$ cm^3	$Z = 10{,}5k_s h_4 S\,l_e^2$ cm^3
(b) Inertia	–	$I = \dfrac{2{,}5}{k_s}\,l_e Z$ cm^4

Symbols

s, S, k_s, as defined in Table 3.2.1
l_e = effective length of stiffening member in metres and for bulkhead stiffeners, *see* Fig. 3.3.3
f_s = 1,4 for rolled or built sections and double plate bulkheads
= 1,6 for flat bars
= 1,1 for symmetrical corrugations of deep tank bulkheads
= 1,0 for symmetrical corrugations of watertight bulkheads
h_4 = $0{,}1P_{bhp}$ for deep tank and watertight bulkhead plating
= $0{,}1P_{bhs}$ for deep tank and watertight stiffening
P_{bhp} and P_{bhs} are the bulkhead design pressures as defined in Pt 5, Ch 3,5.8
ω_1 and ω_2 are bulkhead end constraint factors, *see* Fig. 3.3.3
β = aspect ratio correction factor, *see* Ch 2,2.5.1

NOTES
1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where watertight bulkheads are required by Pt 3, Ch 2,4.
2. Corrugated bulkheads are to comply with the requirements of Ch 2,2.3. Both the plate panels and section inertia and modulus requirements are to be assessed.





l, k_s, s as defined in Ch 2,1.3.1

B = adjacent member

A = member under consideration

Z_A, Z_B = modulus of member in cm^3

$M_1 = \dfrac{h_4\, s\, l_e^2}{51}$ for watertight bulkheads

$= \dfrac{h_4\, s\, l_e^2}{28}$ for deep tank bulkheads

a = bracket length, in metres, *see* Ch 2,3.2

t_A, t_B = thickness of member, in mm

d_A, d_B = web depth of member, in mm

l_e = effective length = $(l - e_1 - e_2)$, in metres

f_{BK} = bracket stiffening factor
1,0 for flanged and fixed ends
0,7 for flanged and sniped ends
0,5 for unflanged

$d = 1{,}0$ or $0{,}932\dfrac{k_s}{\xi}$ for watertight bulkheads

ξ = 1,0 for full continuity of bulkheads

$= \dfrac{\eta t_m \sqrt{k_s}}{b} + 0{,}333$ but not less than 1,0 nor greater than 1,333 where there is not full continuity

ν = 50 for welded sections
= 60 for cold formed sections

Fig. 3.3.3 Bulkhead end constraint factors

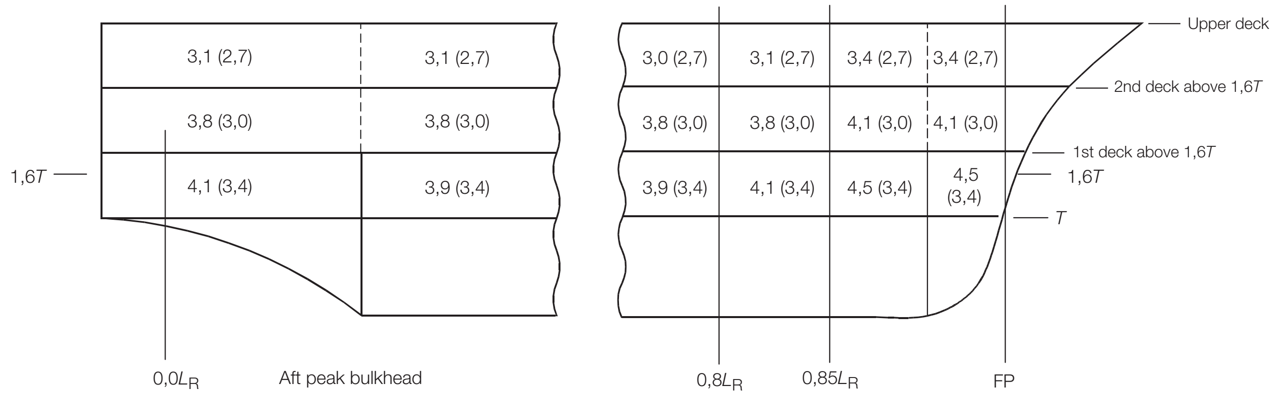


Fig. 3.3.4 Framing Factors C_2 (C_3)

Table 3.3.6 Deck plating

Location	Minimum thickness, in mm, *see also* Ch 3,2.2	
	Longitudinal framing	Transverse framing
(1) Strength deck $0{,}3L_R$ to $0{,}7L_R$ (*see* Notes 1, 2 and 6)	The greater of the following: (a) $t = 9{,}0s_1\,(0{,}059L_1 + 7)\sqrt{\frac{F_D}{k_L}} \times 10^{-4}$ (b) $t = (7{,}4s_1\sqrt{L_R\,k_s} \times 10^{-4}) + 1{,}5$	The greater of the following: (a) $t = s_1\,f\,(0{,}083L_1 + 10)\sqrt{\frac{F_D}{k_L}} \times 10^{-4}$ (b) $t = 0{,}001s_1\sqrt{L_R\,k_s} + 2{,}0$
(2) Weather deck and exposed decks (*see* Note 2)	$t = (7{,}4s_1\sqrt{L_R\,k_s} \times 10^{-4}) + 1{,}5$	$t = (7{,}4s_1\sqrt{L_R\,k_s} \times 10^{-4}) + 1{,}0$
(3) Lower decks (a) effective (continuous) (b) non effective	$t = 0{,}011s_1\sqrt{k_s}$ $t = 0{,}009s_1\sqrt{k_s}$	
(4) Strength deck forward of $0{,}925L_R$ and aft of $0{,}075L_R$	$t = (5{,}0 + 0{,}018L_R)\sqrt{\frac{k_s\,s_1}{s_b}}$	
(5) Plating forming the upper flange of underdeck girders	Clear of deck openings, $t = \sqrt{\frac{A_f}{2{,}2k_s}}$ In way of deck openings, $t = 1{,}1\sqrt{\frac{A_f}{2{,}2k_s}}$ Minimum breadth, b = 760 mm	

Symbols

s, S, L_1, ρ, k_L, k_s, f as defined in 3.2.1
L_R as defined in Pt 3, Ch 1,5.2
s_1 as defined in Table 3.3.1
b = breadth of increased plating, in mm
s_b = as defined in Table 3.3.1, except of aft of $0{,}05L_R$ equal to 850 mm
F_D = as defined in 3.6
A_f = girder face area in cm^2

NOTES
1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Ch 2,4 and minimum thickness requirements.
2. The deck thickness is to be not less than the basic end deck thickness as given in (4)
3. Where a deck loading exceeds 43,2 kN/m^2, the thickness of plating will be specially considered.
4. The exposed deck taper thickness is to extend into a forecastle or poop for at least one third of the beam, B, from the superstructure end bulkhead.
5. For decks forming the boundary of a tank the plating thickness is to be 1,0 mm in excess of the requirements in Table 3.3.5 (1) for deep tanks.
6. Strength deck plating from $0{,}075L_R$ to $0{,}3L_R$ and $0{,}7L_R$ to $0{,}925L_R$ is to be determined by assuming a linear taper from the midship value (1) to $t = (5{,}0 + 0{,}018L_R)\sqrt{k_s}$ at $0{,}075L_R$ and $0{,}925L_R$. The plating thickness determined is not to be less than (4). The total area of strength deck plating at $0{,}075L_R$ and $0{,}925L_R$ is not to be less than 30 per cent of the midship value, *see* 3.7.

Table 3.3.7 Deck longitudinals (longitudinal framing)

Location	Modulus, in cm^3
(1) Strength deck $0,3L_R$ to $0,7L_R$	$Z = 0{,}039\, s\, k_s\, h_{T1}\, l_e^2\, F_1$
(2) Weather deck and exposed deck (a) $0,075L_R$ to $0,8L_R$ (b) Weather deck fwd of $0,8L_R$ (*see* Note 3) (c) Weather deck aft of $0,075L_R$	 $Z = s\, k_s\, (360h_1 + 0{,}0045\, (l_e\, L_2)^2) \times 10^{-4}$ $Z = f_L\, s\, k_s\, (360h_1 + 0{,}0045\, (l_e\, L_1)^2) \times 10^{-4}$ $Z = 0{,}0067s\, k_s\, h_1\, l_e^2$ or (a) above whichever is greater
(3) Lower decks (a) Stores, machinery and hangar decks (i) effective (ii) non effective (b) Accommodation decks (*see* Note 1) (i) effective (ii) non effective	 $Z = s\, k_s\, (5{,}4L_1 + 23h_2\, l_e^2) \times 10^{-4}$ $Z = 0{,}0045s\, k_s\, h_2\, l_e^2$ $Z = s\, k_s\, (4{,}7L_1 + 23h_2\, l_e^2) \times 10^{-4}$ $Z = 0{,}0039s\, k_s\, h_2\, l_e^2$
(4) Strength deck in way of superstructure	To be specially considered
Symbols	
ρ, L_1,L_2, s, k_s as defined in 3.2.1 D, T, L_R as defined in Pt 3,Ch 1,5.2 F_D = as defined in 3.6 $C_1 = \dfrac{60}{225 - 165F_D}$ d_w = web depth of longitudinal, in mm, *see* Note 2 $F_1 = 0{,}25C_1$ l_e = as defined in Ch 2,2.6, but not to be taken less than 1,5 m h_{T1} = the greater of $\dfrac{L_1}{70}$ or 1,20 m $f_{FB} = \dfrac{0{,}0914 + 0{,}003L_R}{D - T} - 0{,}15$	h_2 = deck pressure head (*see* Note 4) = 2,6 for machinery spaces, workshops or hangers = 2,0 for stores = 1,2 for accommodation decks fwd of $0,925L_R$ f_L = 1,57 h_1 = 1,8 from $0,88L_R$ to $0,925L_R$ f_L = 1,43 h_1 = 1,5 aft of $0,88L_R$ f_L = 1,23 (*see* Note 3) $h_1 = 1{,}2 + 2{,}04f_{FB}$

NOTES
1. Where weather decks are intended to carry deck equipment and the load is in excess of 8,5 kN/m^2, the scantlings of longitudinals will be specially considered.
2. The web depth of longitudinals, d_w is to be not less than 60 mm.
3. For taper end modulus calculation $f_L = 1{,}23$ at $0,925L_R$
4. Where the deck forms the boundary of a tank, the additional requirements of Table 3.3.5 for deep tanks are to be applied.
5. The modulus of strength deck longitudinals from $0,075L_R$ to $0,3L_R$ and $0,7L_R$ to $0,925L_R$ is to be determined by assuming a linear taper from the midship value (1) to the basic weather deck value (2) at $0,075L_R$ and $0,925L_R$. The modulus determined is not to be less than 2(b) or 2(c), as appropriate, *see* 3.7. The total area of longitudinals at $0,075L_R$ is not to be less than 50 per cent of the midships value.

3.13 Superstructure, deckhouses and bulwarks

3.13.1 The thickness of deck plating is to be as required by Table 3.3.9.

3.13.2 The scantlings of deckhouse and superstructure side, ends and deck stiffening are to comply with the requirements of Table 3.3.10.

3.13.3 The section modulus of deck girders and transverses is to be in accordance with the requirements of 3.12.3 using H_g equal to $0{,}1P_{wd}$, $0{,}1P_{dh}$ or $0{,}1P_{in}$ as appropriate, where P_{wd}, P_{dh} and P_{in} are defined in Pt 5, Ch 3,3.5.

3.13.4 The thickness of the superstructures and deckhouses is in no case to be less than the appropriate minimum requirements given in Section 2.

3.13.5 Additional requirements for superstructures, deckhouses and bulwarks are indicated in Section 11.

3.13.6 Superstructure deckhouse and bulwark stiffeners are to be continuous or efficiently bracketed top and bottom. Where this is impractical the modulus is to be increased by 20 per cent and the ends welded to the deck all round.

3.14 Single and double bottom structures

3.14.1 Single bottom scantlings are to comply with the appropriate minimum requirements given in Section 2. For the forward region, the requirements of Table 3.3.12 are to be complied with.

3.14.2 Double bottom scantlings are to comply with Table 3.3.11 and the appropriate minimum requirements given in Section 2.

Table 3.3.8 Deck beams (transverse framing)

Location	Modulus, in cm^3
(1) Strength, weather and exposed decks	The lesser of the following: (a) $Z = (K_1 K_2 T D + K_3 B_1 s h_1 l_e^2) k_s \times 10^{-4}$ (b) $Z = 2K_3 B_1 s k_s h_1 l_e^2 \times 10^{-4}$
(2) Lower decks	
(a) Stores, machinery and hanger decks	$Z = (360 K_1 T D + 35 s h_2 l_e^2) k_s \times 10^{-4}$
(b) Accommodation decks	$Z = (480 K_1 T D + 35 s h_2 l_e^2) k \times 10^{-4}$

Symbols

s, k_s as defined in 3.2.1
B, D, T as defined in Pt 3, Ch 1,5.2
d_w = depth of beam, in mm
h_1 = strength/weather deck head in metres, *see* Table 3.3.7
h_2 = deck pressure head in metres, *see* Table 3.3.7
l_e as defined in Ch 2,2.6 but to be taken as not less than 1,83 m
B_1 = B, but need not be taken greater than 21,5 m
K_1 = a factor dependent on the number of decks (including poop and bridge superstructures) at the position of the beam under consideration:

1 deck	18,0	3 decks	9,5
2 decks	12,0	4 or more	8,4

K_2 = a factor dependent on the location of the beam:

at short bridge and poops	133
fwd of 0,88L_R	800
elsewhere	530

K_3 = a factor dependent on the location of the beam:

span adjacent to the ship side	3,3
fwd of 0,925L_R	5,0
elsewhere	3,0

NOTES
1. Where weather decks are intended to carry deck cargo and the load is in excess of 8,5 kN/m^2, the scantlings of beams may be required to be increased to comply with the requirements for location (2).
2. The web depth of beams, d_w, is to be not less than 60 mm.
3. Where decks form the boundary of a tank, the additional requirements of Table 3.3.5 for deep tanks is to be applied.

Table 3.3.9 Superstructure plating

Location	Thickness, in mm
(1) Superstructure and deckhouse fronts, sides and backs	$t = 0{,}00126 s \beta \sqrt{k_s P_{dh}}$
(2) Exposed decks in superstructures and deckhouses	$t = 0{,}00126 s \beta \sqrt{k_s P_{wd}} + 1{,}5$
(3) Internal decks in superstructures and deckhouses	$t = 0{,}009 s \beta \sqrt{k_s}$

Symbols

s, f, k_s as defined in 3.2.1
P_{dh} = deckhouse pressure, *see* Pt 5, Ch 3,5.5
P_{wd} = weather deck pressure, *see* Pt 5, Ch 3,3.5
β = aspect ratio correction factor, *see* Ch 2,2.5.1

NOTE
Deckhouses and superstructures subjected to hull girder stress are to comply with the buckling requirements of Ch 2,4.

Table 3.3.10 Superstructure framing

Location	Modulus, in cm^3
Superstructure and deck-house fronts, sides and backs: side longitudinals and side frames (*see* Note 1)	$Z = 0{,}0006 P_{dh} s k_s l_e^2$
Exposed decks: deck beams and deck longitudinals, (*see* Note 2)	The greater of the following: (a) $Z = 0{,}0006 P_{wd} s k_s l_e^2$ (b) $Z = 0{,}025 s$
Internal decks: deck beams and deck longitudinals	The greater of the following: (a) $Z = 0{,}0006 P_{in} s k_s l_e^2$ (b) $Z = 0{,}025 s$

Symbols

s, k_s as defined in 3.2.1
l_e = effective length of stiffening member as defined in Ch 2,2.6
f_{FB} = *see* Table 3.3.7
P_{dh} = deckhouse pressure, *see* Pt 5,Ch 3,3.5
P_{wd} = weatherdeck pressure, *see* Pt 5, Ch 3,3.5
P_{in} = internal deck pressure, *see* Pt 5, Ch 3,5.3

NOTES
1. The section modulus of side frames forming part of the side shell are to comply with the requirements for shell envelope framing.
2. The section modulus of superstructure stiffening is not to be less than that required by Table 3.3.7 and 3.3.8 for full width superstructures.

Table 3.3.11 Double bottom requirements (0,2L_R to 0,8L_R)

Location	Thickness, in mm
Inner bottom plating, (*see* Note)	$t = 0{,}00122(s + 660)(k_s^2 L_R T)^{0,25}$
Longitudinal framing	modulus, in cm^3
Inner bottom longitudinals	The greater of the following: (a) $Z = (0{,}0017 l_{e1} + 0{,}035) s k_s h_{T2} l_e^2 F_s F_1$ (b) $Z = (0{,}0017 l_{e1} + 0{,}035) s k_s h_{T3} l_e^2 F_s F_1$
Transverse framing	
Inner bottom transverse frames	$Z = 1{,}7 s k_s T l_e \times 10^{-2}$

Symbols

s, k_s, as defined in 3.2.1
L_R, T as defined in Pt 3, Ch 1,5.2
l_{e1}, l_e, h_{T2}, h_{T3}, F_1 as defined in Table 3.3.2
F_s as defined in Table 3.3.3

NOTE
The thickness of the margin plate where fitted, is to be increased by 20 per cent.

Table 3.3.12 Single bottom construction forward, minimum requirements

Area	Item	Requirement
Longitudinal framing minimum requirements		
Centreline girder:	Thickness, in mm	$t = (0{,}007\ d_f + 1)\sqrt{k_s}$
Floors and Girders	Thickness, in mm Depth (d_f), in mm	$t = (0{,}006\ d_f + 1)\sqrt{k_s}$ but need not exceed $12\sqrt{k_s}$ As midship region, *see* Table 3.2.1
Bottom Transverses	Spacing, in m	*See* Pt 3, Ch 2,3.4.4
Transverse framing minimum requirements		
Centreline girder	Thickness, in mm	$t = 0{,}95\sqrt{L_R\ k_s}$ but not less than 6 mm at $0{,}075L_R$ and the basic taper thickness at $0{,}925L_R$
	Modulus, in cm^3	the greater of: $Z = 8\ k_s\ S\ h_5\ l_e^2$ $Z = 8\ k_s\ S\ h_4\ l_e^2$
	Inertia, in cm^4	$I = \dfrac{2{,}5\ l_e^2\ Z}{k_s}$
Floors in tanks	Spacing Depth, in mm Thickness, in mm Face plate area, in cm^2	every frame $d_f = 83D + 150$ or 1400 whichever is the lesser $t = (5{,}5+0{,}23L_2)\sqrt{s_2/800}$ $A_f = 0{,}8S\ k_s\ B$
Girders in tanks	Spacing, in metres Depth, in mm Scantlings	$0{,}003s_f$ as for floors as midship region, *see* Table 3.2.1
Floors in dry spaces	Spacing Scantlings	every frame as midship region, *see* Table 3.2.1
Girders in dry spaces	Spacing, in mm Scantlings	$0{,}003s_f$ as midship region, *see* Table 3.2.1
Symbols		
L_2, S, s, k_s, ρ as defined in 3.2.1 L_R, B, D as defined in Pt 3, Ch 1,5.2 l_e = effective length of stiffening member h_4 = tank head, in metres, as defined in Table 3.3.5 h_5 = distance, in metres, from mid-point of span to the following positions: (a) forward of $0{,}85L_R$: 3 m above the deck height obtained from Pt 3, Ch 2,5.3 (b) at $0{,}8L_R$: the upper deck at side (c) between $0{,}85L_R$ and $0{,}8L_R$, by interpolation between (a) and (b) s_F = transverse frame spacing, in mm s_2 = spacing of stiffener, in mm, but to be taken not less than 800 mm		
NOTES 1. For ships having one or more longitudinal bulkheads the maximum spacing may be increased but is not to exceed that for the midship region. 2. Frame structure is to comply with the requirements of Table 3.3.5 3. *See also* the requirements for bottom slamming and bow flare impact.		

3.14.3 In the forward region, the requirements of Table 3.3.13 are to be complied with.

3.14.4 Additional requirements for single and double bottom structures are indicated in Section 7 and 8.

3.14.5 Where there are large unsupported areas of double bottom and single bottom structure, the designers calculations are to be submitted.

3.15 Fore peak structure

3.15.1 Internal structure in the fore peak is to comply with the requirements of Table 3.3.14.

Table 3.3.13 Double bottom construction forward

Item and parameter	Requirements: Transverse framing	Requirements: Longitudinal framing
(1) Centreline girder: (a) Thickness forward of $0,075L_R$ from the F.P.	$t = (0,007\ d_{DB} + 2)\sqrt{k_s}$ mm (*see* Note 2)	
(2) Plate floors: (a) Maximum spacing forward of $0,8L_R$ (b) Maximum spacing aft of $0,8L_R$ (c) Scantlings	$0,002s_F$ m As for midship region As for midship region	2,5 m As for midship region, *see* Table 3.2.1 As for midship region, *see* Table 3.2.1
(3) Watertight floors and bracket floors	As for midship region	As for midship region
(4) Side girders (*see* Note 1): (a) Maximum spacing forward of $0,8L_R$ (b) Maximum spacing aft of $0,8L_R$ (c) Scantlings	$0,003s_F$ m As for midship region As for midship region	$0,004s_L$ or 3,7 m whichever is the lesser As for midship region, *see* Table 3.2.1 As for midship region, *see* Table 3.2.1
(5) Inner bottom plating (*see* Note 2): (a) Thickness at or forward of $0,925L_R$	$t = (0,00115\ (s + 660)\sqrt[4]{k_s^2\ L_R T}\ )$ mm or 5,5 mm, whichever is the greater, *see* Note 2	
(b) In way of deep tanks or holds used for the carriage of water ballast or where the double bottom tank is common with a wing ballast tank	$t = 0,0057S\ \beta\sqrt{h_4\ k_s}$ mm or 5,5 mm, whichever is the greater	
(6) Inner bottom longitudinals	As for midship region	

Symbols

L_R, T, as defined in Pt 3, Ch 1,5.2
S, s, k_s, as defined in 3.2.1
d_{DB}= minimum depth of centre girder as required by Table 3.2.1
h_4 = tank head, in metres, as defined in Table 3.3.6
s_F = transverse frame spacing, in mm
s_L = spacing of bottom longitudinals, in mm
β = aspect ratio correction factor, Ch 2,2.5.1.

NOTES
1. The girders forward of $0,8L_R$ are to be suitably scarfed into the midship girder arrangement.
2. From $0,7L_R$ to $0,925L_R$ the taper thickness is to be used.

Table 3.3.14 Fore peak structure

Item	Parameter	Requirement
(1) Perforated flats and wash bulkheads excluding lowest strake of plating (*see* note 1)	Plating thickness Stiffener modulus	$t = (5,5 + 0,013L_R)\sqrt{s_1/800}$ mm $Z = \dfrac{0,0052s\ k_s\ h_6\ l_e^2}{f_s}$
(2) Diaphragms in bulbous bows and the lowest stake of plating	Plating thickness	$t = (5,5 + 0,023L_R)\sqrt{s_1/800}$ mm

Symbols

L_R as defined in Pt 3, Ch 1,5.2
s, k_s as defined in 3.2.1
f_s = 1,4 for rolled or built sections
1,6 for flat bars
h_6= vertical distance, in metres, from the mid depth of the tank to the top of the tank
l_e = effective length of the stiffening member, *see* Ch 2,2.6
s_1 = spacing of stiffeners, in mm, but to be taken not less than 800 mm

NOTES
For horizontal flats supporting vertical webs in the fore peak tank the thickness of the flat in the web is to comply with the requirements of $t = a/\ (80 + 20a/b)\sqrt{k_s}$ for horizontal stiffening or $t = a/\ (73 + 27(a/b)^2)\sqrt{k_s}$ for vertical stiffening

where
a is lesser dimension of the unstiffened plate panel.
b is the greater dimension of the unstiffened plate panel.

Section 4
NS2 and NS3 scantling determination

4.1 General

4.1.1 The scantlings for NS2 and NS3 ships may be determined from the global and local requirements defined in this Section. In addition, the general requirements of Sections 5 to 15 are to be complied with.

4.1.2 This section contains various Tables indicating the design pressures, beam models and stiffener type coefficients which may be used in conjunction with the appropriate scantling formulae indicated in Chapter 2 and the structural design factors in Chapter 5 to determine the required scantlings for both plating and stiffening members of NS2 and NS3 type ships.

4.1.3 In the determination of scantlings for stiffening members assumptions have been made about the degree of end fixity in way of their end connections. Where it can be demonstrated that the degree of end fixity is greater than that assumed then consideration will be given to lesser scantling requirements. In such cases the builders/designers are to submit sufficient information to enable an assessment of the degree of end fixity to be made and are to obtain acceptance of their proposals prior to submission of the scantling plans.

4.1.4 The geometric properties of stiffener sections are to be in accordance with Ch 2,2.9.

4.1.5 The scantlings in this Section are based on the assumption that there is negligible loss in strength from corrosion.

4.1.6 The corrosion margins specified in Ch 6,2.10 are to be applied to the derived scantlings as appropriate, *see also* Ch 1,2.2.1.

4.2 Hull girder strength

4.2.1 For all ships, the hull girder strength requirements of Ch 4,2 are to be complied with.

4.2.2 As required by Ch 4,2, the hull girder bending and shear stresses for all longitudinally effective material is to be checked against the permissible stresses and the buckling requirements of Ch 2,4. The lateral and torsional stability of all effective longitudinals, together with the web and flange buckling criteria, are to be verified in accordance with Ch 2,4.

4.3 Shell envelope plating

4.3.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

4.3.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

4.3.3 Additional requirements for shell envelope plating are indicated in Section 5.

4.3.4 The thickness requirement for shell envelope plating may be determined from the general equations given in Ch 2,2.7, the pressures given in Table 3.4.1 and the structural design factors in Chapter 5.

4.3.5 For NS3 ships the minimum thickness requirement for bottom shell plating, *see* Fig. 3.4.1, as detailed in Section 2, is to extend to the chine line or 150 mm above the design waterline, whichever is the greater.

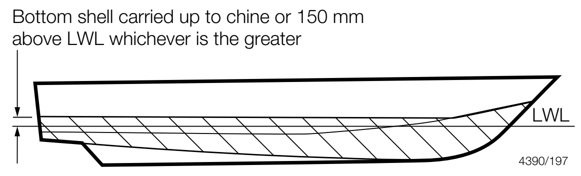


Fig. 3.4.1 Extent of bottom shell

4.3.6 Where a chine or knuckle is fitted between the bottom shell and side shell plating, the chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

4.3.7 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

4.3.8 Full penetration welding of shell plating in way of chine is to be maintained.

4.3.9 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration, *see* Fig. 3.4.2.

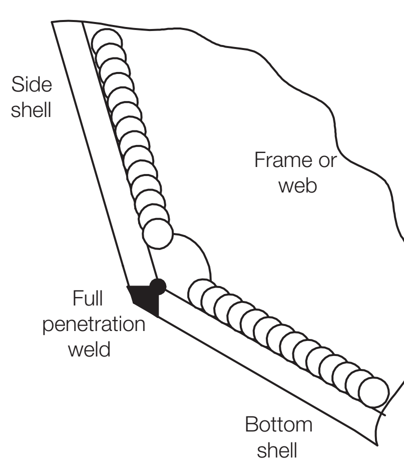


Fig. 3.4.2 Chine detail

4.4 Shell envelope framing

4.4.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

4.4.2 Additional requirements for shell envelope framing are indicated in Section 6.

4.4.3 The section modulus, inertia and web area requirements for shell envelope stiffening may be determined from the general equations given in Ch 2,2.8, the pressures given in Table 3.4.2 and the structural design factors in Chapter 5.

Table 3.4.1 Shell envelope plating

Structural element	Design pressure
Bottom plating Bilge plating Side shell plate Sheerstrake	Below waterline, the greater of (a) $P_h + 1{,}26P_w$ (b) $1{,}26P_{dl}$ Above the waterline $1{,}26P_s$
Symbols	
P_h = the hydrostatic pressure on the shell plating, as defined in Pt 5, Ch 3,3.3 P_w = the hydrodynamic wave pressure on the shell plating, as defined in Pt 5, Ch 3,3.4 P_s = the design pressure on the shell envelope, as defined in Pt 5, Ch 3,3.2 P_{dl} = the bottom impact pressure for planing hull forms as defined in Pt 5, Ch 3,4.5. This is not applicable for displacement hull forms.	

Table 3.4.2 Shell envelope framing

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
Longitudinal framing				
Bottom and bilge longitudinals Side longitudinals	Below waterline (a) $\delta_f (P_h + 1{,}26P_w)$ (b) $\delta_f\ 1{,}26P_{dl}$ Above waterline $\delta_f\ 1{,}26P_s$	B	0,8	*See* Note 1
Transverse framing				
Bottom transverse frames Side frames	Below waterline (a) $\delta_f (P_h + 1{,}26P_w)$ (b) $\delta_f (P_h + 1{,}26P_{dl}$ Above waterline $\delta_f\ 1{,}26P_s$	B	0,8	*See* Note 1
Primary structure				
Bottom girders Side stringer Floors Bottom transverse web frames Side transverse web frames	Below waterline (a) $\delta_f (P_h + 1{,}26P_w)$ (b) $\delta_f\ 1{,}26P_{dl}$ Above waterline $\delta_f\ 1{,}26P_s$	A	0,5	*See* Note 2
Symbols				
P_h = the hydrostatic pressure on the shell envelope, as defined in Pt 5, Ch 3,3.3 P_w = the hydrodynamic wave pressure on the shell envelope, as defined in Pt 5, Ch 3,3.4 P_s = the design pressure on the shell envelope, as defined in Pt 5, Ch 3,3.2 P_{dl} = the bottom impact pressure for planing hull forms, as defined in Pt 5, Ch 3,4.5. This is not applicable for displacement hull forms.				
NOTES 1. Longitudinal and transverse frame stiffeners are secondary stiffening members, *see* Pt 3, Ch 2,2.3.1. In general, secondary stiffening members are to be designed using load model 'B', *see* Table 2.2.1 in Chapter 2. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing. 2. Guidelines for the design of primary stiffening members are given in Pt 3, Ch 2,3.2.1. In general, primary stiffening members are to be designed using load model 'A', *see* Table 2.2.1 in Chapter 2. Primary members are to be substantially bracketed at their end connections.				

4.5 Inner bottom structures

4.5.1 The requirements of this Section are applicable to longitudinally and transversely framed inner bottom structure.

4.5.2 The thickness of the inner bottom plating is in no case to be less than the appropriate minimum requirement given in Section 2.

4.5.3 Additional requirements for inner bottom structures are indicated in Section 8.

4.5.4 The thickness requirement for inner bottom plating may be determined from the general equations given in Ch 2,2.7, the pressures given in Table 3.4.3 and the structural design factors in Chapter 5.

4.5.5 The section modulus, inertia and web area requirements for inner bottom stiffening may be determined from the general equations given in Ch 2,2.8, the pressures given in Table 3.4.3 and the structural design factors in Chapter 5.

4.6 Watertight bulkheads and deep tanks

4.6.1 The requirements of this Section are applicable to longitudinally and transversely framed watertight bulkhead and deep tank structure.

4.6.2 The thickness of the bulkhead plating is in no case to be less than the appropriate minimum requirement given in Section 2.

4.6.3 Additional requirements for watertight bulkhead and deep tank structure are indicated in Section 9.

4.6.4 The thickness requirement for bulkhead plating may be determined from the general equations given in Ch 2,2.7, the pressures given in Table 3.4.4 and the structural design factors in Chapter 5.

4.6.5 The section modulus, inertia and web area requirements for bulkhead stiffening may be determined from the general equations given in Ch 2,2.8, the pressures given in Table 3.4.4 and the structural design factors in Chapter 5.

4.7 Deck structures

4.7.1 The requirements of this Section are applicable to longitudinally and transversely framed deck structure.

4.7.2 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

4.7.3 Additional requirements for deck structures are indicated in Section 10.

4.7.4 The thickness requirement for deck plating may be determined from the general equations given in Ch 2,2.7, the pressures given in Table 3.4.5 and the structural design factors in Chapter 5.

4.7.5 The section modulus, inertia and web area requirements for deck stiffening may be determined from the general equations given in Ch 2,2.8, the pressures given in Table 3.4.5 and the structural design factors in Chapter 5.

Table 3.4.3 Inner bottom structures

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
Inner bottom plating	$P_{hd} + P_{w,da}$	—	—	
Longitudinal framing				
Inner bottom longitudinals	$\delta_f (P_{hd} + 1{,}26P_{w,da})$	B	0,8	*See* Note 1
Transverse framing				
Inner bottom transverse frames	$\delta_f (P_{hd} + 1{,}26P_{w,da})$	B	0,8	*See* Note 1

Symbols

P_{hd} is the P_h value for the local damaged draft, where P_h is the hydrostatic pressure on the shell envelope, as defined in Pt 5, Ch 3,3.3

$P_{w,da}$ = the hydrodynamic wave pressure on the shell envelope, P_w, as defined in Pt 5, Ch 3,3.4, but based on a reduction in the local wave height for the damaged situation. The local wave height factor, f_{Hs}, used to derive P_w may be taken as specified in Pt 5, Ch 3,1.2.2 but may be reduced by a factor of 1,85. Hence $P_{w,da} = P_w/1{,}85$

NOTES
1. Longitudinal and transverse frame stiffeners are secondary stiffening members, *see* Pt 3, Ch 2,2.3.1. In general, secondary stiffening members are to be designed using load model 'B', *see* Table 2.2.1 in Chapter 2. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.
2. Where the inner bottom forms the boundary of a deep tank, the deck is to be examined for compliance with the requirements for deep tanks, *see* Table 3.4.4.
3. Where the inner bottom forms the boundary of a watertight subdivision, the inner bottom is to be examined for compliance with the requirements for watertight bulkheads, *see* Table 3.4.4.
4. Where the inner bottom is subject to cargo deck or internal deck loadings, the inner bottom is to be examined for compliance with the requirements for lower decks and internal decks, *see* Table 3.4.5.
5. Where the inner bottom is subject to wheel loadings arising from vehicles or helicopters/aircraft, the inner bottom is to be examined for compliance with the requirements for vehicle decks, *see* Pt 4, Ch 3,2, or aircraft operation, *see* Pt 4, Ch 2,10, as appropriate.

Table 3.4.4 Watertight and deep tank bulkhead scantlings

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
(1) Watertight bulkheads and decks				
Plating	P_{bhp}	—	—	
Secondary stiffeners	P_{bhs}	B	—	*See* Note 1
Primary stiffeners	P_{bhs}	A	—	*See* Note 2
(2) Deep tank bulkheads and decks				
Plating	P_{bhp}	—	—	
Secondary stiffeners	P_{bhs}	B	—	*See* Note 1
Primary stiffeners	P_{bhs}	A	—	*See* Note 2
(3) Collision bulkhead				
Plating	P_{bhp}	—	—	
Secondary stiffeners	P_{bhs}	B	—	*See* Note 1
Primary stiffeners	P_{bhs}	A	—	*See* Note 2

Symbols

P_{bhp} and P_{bhs} are the watertight bulkhead and deep tank pressure values for the plate panel and stiffener respectively, as defined in Pt 5, Ch 3,5.5.

P_{bhp} and P_{bhs} pressure values for the plate panel and stiffeners of the collision bulkhead are defined in Pt 5, Ch 3,5.9

NOTES
1. Secondary stiffening members are, in general, defined in Pt 3, Ch 2,2.3.1. In general, secondary stiffening members are to be designed using load model 'B', *see* Table 2.2.1 in Chapter 2. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.
2. Guidelines for the design of primary stiffening members are given in Pt 3, Ch 2,2.3.1. In general, primary stiffening members are to be designed using load model 'A', *see* Table 2.2.1 in Chapter 2. Primary members are to be substantially bracketed at their end connections.

4.8 Superstructure, deckhouses and bulwarks

4.8.1 The requirements of this Section are applicable to longitudinally and transversely framed superstructure, deckhouse and bulwark structures.

4.8.2 The thickness of the superstructure and deckhouse plating is in no case to be less than the appropriate minimum requirement given in Section 2.

4.8.3 Additional requirements for superstructure, deckhouse and bulwark structures are indicated in Section 11.

4.8.4 The thickness requirement for superstructure deckhouse and bulwark may be determined from the general equations given in Ch 2,2.7, the pressures given in Table 3.4.6 and the structural design factors in Chapter 5.

4.8.5 The section modulus, inertia and web area requirements for superstructure, deckhouse and bulwark stiffening may be determined from the general equations given in Ch 2,2.8, the pressures given in Table 3.4.6 and the structural design factors in Chapter 5.

Table 3.4.5 Deck structures

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
(1) Weather decks and exposed decks				
Plating	The greater of (a) $1,26P_{wd}$ (b) P_{cd}	–	–	–
Secondary stiffening Deck longitudinals or deck beams	The greater of (a) $\delta_f\ 1,26P_{wd}$ (b) P_{cd}	B	0,8	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	The greater of (a) $\delta_f\ 1,26P_{wd}$ (b) P_{cd}	A	0,5	*See* Note 2
(2) Lower decks and internal decks				
Plating	The greater of (a) P_{in} (b) P_{cd}	–	–	–
Secondary stiffening Deck longitudinals or deck beams	The greater of (a) P_{in} (b) P_{cd}	B	–	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	The greater of (a) P_{in} (b) P_{cd}	A	–	*See* Note 2
(3) Ramps and lifts				
Plating	P_{ra}	–	–	–
Secondary stiffening Deck longitudinals or deck beams	P_{ra}	B	–	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	P_{ra}	E	–	*See* Note 3

Symbols

P_{wd} = the pressure acting on exposed and weather decks, as defined in Pt 5, Ch 3,3.5, *see also* Pt 5, Ch 3,5.2
P_{in} = the pressure acting on internal decks, as defined in Pt 5, Ch 3,5.3
P_{cd} = the pressure acting on decks designed to carry cargo or heavy equipment loads, as defined in Pt 5, Ch 3,5.4, where appropriate
P_{ra} = the pressure on ramps and lifts, as defined in Pt 5, Ch 3,6.2

NOTES
1. In general, secondary stiffening members are to be designed using load model 'B', *see* Table 2.2.1 in Chapter 2. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.
2. Guidelines for the design of primary stiffening members are given in Pt 3, Ch 2,3.2.1. In general, primary stiffening members are to be designed using load model 'A', *see* Table 2.2.1 in Chapter 2. Primary members are to be substantially bracketed at their end connections.
3. In general, primary lift and ram stiffening members are to be designed using load model 'E', *see* Table 2.2.1 in Chapter 2.
4. Where a deck forms the boundary of a deep tank, the deck is to be examined for compliance with the requirements for deep tanks, *see* Table 3.4.4.
5. Where a deck forms the boundary of a watertight subdivision or part of the shell envelope, the deck is to be examined for compliance with the requirements for watertight bulkheads, *see* Table 3.4.4, or the shell envelope respectively, *see* Table 3.4.2.
6. Where a deck is subject to wheel loadings arising from vehicles or helicopters/aircraft, such decks are to be examined for compliance with the requirements for vehicle decks, *see* Pt 4, Ch 3,2, or aircraft operation, *see* Pt 4, Ch 2,10, as appropriate.

Table 3.4.6 Superstructure, deckhouse and bulwark structures

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
(1) Superstructure sides, fronts and backs Deckhouse sides, fronts and backs				
Plating	$1,26P_{dh}$	–	–	
Secondary stiffening Side longitudinals Side frames	δ_f $1,26P_{dh}$	B	0,8	*See* Note 1
Primary stiffening Side stringers Side web frames	δ_f $1,26P_{dh}$	A	0,5	*See* Note 2
(2) Superstructure exposed decks Deckhouse exposed decks				
Plating	$1,26P_{wd}$	–	–	
Secondary stiffening Deck longitudinals Deck beams	δ_f $1,26P_{wd}$	B	0,8	*See* Note 1
Primary stiffening Deck girders Deck transverses or deep beams	δ_f $1,26P_{wd}$	A	0,5	*See* Note 2
(3) Superstructure internal decks Deckhouse internal decks				
Plating	P_{in}	–	–	
Secondary stiffening Deck longitudinals Deck beams	P_{in}	B	–	*See* Note 1
Primary stiffening Deck girders Deck transverses or deep beams	P_{in}	A	–	*See* Note 2
(4) Bulwarks				
Plating	$1,26P_{dh}$	–	–	
Secondary stiffening Bulwark stays	δ_f $1,26$ P_{dh}	B D	0,8 1,0	*See* Note 1 *See* Note 3

Symbols

P_{wd} = the pressure acting on exposed and weather decks, as defined in Pt 5, Ch 3,3.5, *see also* Pt 5, Ch 3,5.2
P_{in} = the pressure acting on internal decks, as defined in Pt 5, Ch 3,5.3
P_{dh} = the pressure acting on deckhouses, bulwarks and superstructures, as defined in Pt 5, Ch 3,5.5

NOTES
1. In general, secondary stiffening members are to be designed using load model 'B', *see* Table 2.2.1 in Chapter 2. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.
2. Guidelines for the design of primary stiffening members are given in Pt 3, Ch 2,3.2.1. In general, primary stiffening members are to be designed using load model 'A', *see* Table 2.2.1 in Chapter 2. Primary members are to be substantially bracketed at their end connections.
3. Bulwark stays are to be designed using load model 'D', *see* Table 2.2.1 in Chapter 2. The webs of the stays are to be carefully aligned with underdeck stiffeners and hard spots are to be avoided in way of end connections.
4. Where a deck is subject to wheel loadings arising from vehicles or helicopters/aircraft, such decks are to be examined for compliance with the requirements for vehicle decks, *see* Pt 4, Ch 3,2, or aircraft operation, *see* Pt 4, Ch 2,10, as appropriate.

Section 5
Shell envelope plating

5.1 General

5.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

5.1.2 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating. The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The arrangement of shell plating is to be in accordance with Pt 3, Ch 2,3.3.

5.1.3 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirements given in Section 2.

5.1.4 Ships which operate aground are to comply with the requirements of Pt 4, Ch 3.

5.1.5 For ships with external blast notation the side shell above the waterline is to be in accordance with Pt 4, Ch 2.

5.1.6 Where appropriate all ship types are to comply with the requirements of Section 14 for bottom slamming and Section 15 for bow flare impact or wave impact above the waterline.

5.2 Plate keel

5.2.1 The width and thickness of the plate keel are to be maintained throughout the ship from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Table 3.2.1 for the stem. For ships with an after cut up, the keel thickness aft of the cut up can be reduced to that of the shell plating.

5.2.2 Cast or forged stems are to comply with the requirements of Pt 2, Ch 3 for rolled steel flat bars, or Pt 2, Ch 5 for solid round bars. Cast or forged pieces or inserts are to comply with Pt 2, Ch 4 or Ch 5 as appropriate.

5.3 Sheerstrake

5.3.1 The sheerstrake thickness is to be increased by 20 per cent at the ends of a superstructure extending out to the ship's side. In the case of a superstructure longer than $0,15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the sheerstrake.

5.3.2 Where an angled gunwale is fitted, the top edge of the sheerstrake is to be kept free of all notches and isolated welded fittings, such as spurnwaters, fairlead stools, stancheons. Bulwarks are not to be welded to the top of the sheerstrake within 0,3 to $0,7L_R$.

5.3.3 Where a rounded gunwale is adopted, the welding of fairlead stools, spurnwaters, stancheons and other fittings to this plate is to be kept to the minimum, and the design of the fittings is to be such as to minimise stress concentration. The radius in general is not to be less than $15t_p$.

5.3.4 For ships with a shock enhanced notation, *see* Pt 4, Ch 2,5.

5.4 Skegs

5.4.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell.

5.5 Transom

5.5.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

5.6 Shell openings

5.6.1 The thickness of the shell envelope plating around sea inlet or other opening is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater. Arrangements are to be in accordance with Pt 3, Ch 2,3.3.

5.6.2 The detail and steel grade corners of large openings in the side shell will be specially considered. Generally they are to be in accordance with the requirements for large deck openings, *see* 10.4.1.

5.7 Sea inlet boxes

5.7.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater. If the thickness of the adjacent shell plating is greater than 12,5 mm, the sea inlet box may be the same thickness as the shell and it need not exceed 25 mm.

5.7.2 Arrangements are to be in accordance with Pt 3, Ch 2,3.3. Stiffeners are to be suitably supported by brackets or equivalent.

5.8 Local reinforcement/Insert plates

5.8.1 The thickness of the shell envelope plating is to be increased locally in way of sternframe, propeller brackets, rudder horn, stabilizers, hawse pipes, anchor recess, sea inlets, sonar openings, etc., by generally not less than 50 per cent. Details of such reinforcement are to be submitted for approval.

5.8.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 6,5.6.

5.9 Novel features

5.9.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 6* Shell envelope framing

6.1 General

6.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

6.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes. The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The arrangement of framing is to be in accordance with Pt 3, Ch 2,3.4.

6.1.3 The geometric properties of stiffener sections are to be in accordance with Ch 2,2.9.

6.1.4 Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length. *See also* Ch 6,5.3.

6.1.5 Stiffeners and brackets on side transverses which are connected to higher tensile steel longitudinals are to have their heels well radiused to reduce stress concentrations. Alternative arrangements will be considered if supported by appropriate direct calculations. *See also* Ch 6,5.3.

6.1.6 Where higher tensile steel side longitudinals pass through transverse bulkheads in the $0,4L_R$ amidships, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection. Particular attention should be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

6.1.7 Where higher tensile steel asymmetrical sections are adopted in double bottom tanks which are interconnected with double skin side tanks the requirements of 6.1.5 and 6.1.6 are to be complied with regarding arrangements to reduce stress concentrations. Alternatively, it is recommended that bulb plate or symmetrical sections are adopted.

6.1.8 Where appropriate all ship types are to comply with the requirements of Section 14 for bottom slamming and Section 15 for wave impact above the waterline.

6.2 Frame struts or cross ties

6.2.1 Where struts are fitted to side shell transverse web frames or longitudinal stringers to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 12. If the strut is fitted at the primary member half span point, the primary member section modulus may be taken as half the modulus derived above.

6.2.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum required cross-sectional area of the strut. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the supporting structure are to be welded using double continuous welding of an equivalent area.

■ *Section 7* Single bottom structures

7.1 General

7.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

7.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The arrangement of single bottoms are to be in accordance with Pt 3, Ch 2,3.5.

7.1.3 The scantlings of the single bottom are to comply with the minimum requirements given in Section 2.

7.1.4 Where appropriate all ships are to comply with the requirements of Section 14 for bottom slamming.

7.1.5 Watertight girders and floors or girders and floors forming the boundaries of tank spaces are to comply with the requirements for watertight bulkheads and deep tanks as detailed in Section 9. Consideration should be given to the addition of a corrosion margin in excess of that specified in Ch 6,2.10.

7.2 Centreline girder

7.2.1 The web depth of the centreline girder is in general to be equal to the depth of the floors at the centreline. The minimum requirements for web depth and thickness are specified in Section 2.

7.2.2 The geometric properties of the centre girder are to be in accordance with Ch 2,2.9. The buckling requirements of Ch 2,4 are to be satisfied.

7.2.3 The face flat area of the centreline girder outside 0,3 to $0,7L_R$ may be 80 per cent of the value given in Section 2.

7.2.4 The face flat thickness is to be not less than the thickness of the web.

7.2.5 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

7.3 Side girders

7.3.1 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in Section 2 and 7.4. The buckling requirements of Ch 2,4 are to be satisfied.

7.4 Floors general

7.4.1 The web thickness, t_w, of plate floors, is to be accordance with Ch 2,2.9 and is to be taken as not less than:
for NS1 ships

$$t_w = 0,9\sqrt{k_s}\left(\frac{d_f}{100} + 3\right) \text{ mm}$$

for NS2 and NS3 ships

$$t_w = \sqrt{k_s}\left(\frac{3,4d_f}{1000} + 2,25\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where
d_f is to be determined from Table 3.2.1
k_s and s are as defined in 3.2.1.

7.4.2 In addition the area of face plate for NS1 ships is not to be less than

$$A_f = 4,5T\,k_s \text{ cm}^2$$

k_s as defined in 3.2.1
T, B as defined in Pt 3, Ch 1,5.2.

7.4.3 If the side frames of the ship are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

7.4.4 The face flat thickness is to be not less than the thickness of the web. The ratio of the web breadth to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

7.4.5 Additionally floors are to comply with the requirements for bottom transverse web frames.

7.5 Single bottom structure in machinery spaces

7.5.1 The arrangement of structure in machinery spaces is to be in accordance with Pt 3, Ch 2,6.

7.5.2 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by 7.4.

7.5.3 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 7.4. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength.

7.5.4 In way of machinery spaces situated amidships the minimum depth of floors is to be at least 10 per cent greater than that required in 7.4. If the top of the floors is recessed in way of the engines, the depth of the floors in way of the recess should generally be not less than that required by 7.4, but this will be specially considered in each case in relation to the arrangements proposed.

7.5.5 The general requirements for machinery or raft seatings are given in Section 13.

7.6 Rudder horns

7.6.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by Section 2. The scantlings of rudder horns will be specially considered.

7.7 Forefoot and stem

7.7.1 The thickness of plate stems at the waterline is to comply with the minimum requirements for plate keels given in Section 2, *see also* 5.2.

7.7.2 The forefoot and stem is to be additionally reinforced with floors.

■ *Section 8*
Double bottom structures

8.1 General

8.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

8.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The scantlings of the double bottom structure are also to comply with the appropriate minimum requirements given in Section 2. The arrangements of double bottoms are to comply with the requirements of Pt 3, Ch 3,2.6.

8.1.3 Where a double bottom is required to be fitted, its depth at the centreline, d_{DB}, is to be in accordance with Section 2.

8.1.4 This Section provides for longitudinal or transverse framing in the double bottom, but for NS1 and NS2 ships longitudinal framing is in general to be adopted. *See* Pt 3, Ch 2,3.1.

8.1.5 Where appropriate all ship types are to comply with the requirements of Section 14 for bottom slamming.

8.1.6 Where a floor, girder or inner bottom plating forms the boundary of a tank or part of the watertight subdivision, the requirements of Section 9 for deep tanks and watertight bulkheads are to be complied with. Consideration should be given to the addition of a corrosion margin in excess of that specified in Ch 6,2.10.

8.2 Centreline girder

8.2.1 A centreline girder is to be fitted throughout the length of the ship. The web thickness, t_w, is not to be less than that required by Section 2.

8.2.2 The geometric properties of the girder section are to be in accordance with Ch 2,2.9. The buckling requirements of Ch 2,4 are to be satisfied.

8.2.3 The depth of the double bottom and centreline girder is to be not less than 630 mm and it is to be sufficient to give access to all of the double bottom.

8.2.4 Where appropriate, vertical stiffeners are to be fitted at every bracket floor. They are to have a depth not less than the depth of the tank top frame or 150 mm, whichever is the greater. For NS2 and NS3 ships stiffeners are to have a depth of not less than $1,65L_R$ mm with a minimum of 50 mm. The thickness is to be as required for the girder.

8.3 Side girders

8.3.1 The thickness of the side girders is not to be less than that of the plate floors. The buckling requirements of Ch 2,4 are to be satisfied.

8.3.2 Vertical stiffeners are to be fitted at every bracket floors fitted and if midway between floors in accordance with 8.2.4.

8.4 Plate floors

8.4.1 The thickness need not be greater than 15 mm but without suitable stiffening the ratio of depth of floor at the centre to thickness must be less than 130.

8.4.2 Vertical stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ or 50 mm and a thickness of not less than t_w, where t_w is the thickness of the plate floor as calculated in Section 2. For NS1 ships, the depth of stiffeners is not to be less than 150 mm.

8.5 Bracket floors

8.5.1 Between plate floors, the shell and inner bottom plating centreline girders and side girders may be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

8.5.2 Where struts are fitted to reduce the unsupported span of the frames, reverse frames and longitudinals, they are to have a cross-sectional area of not less than:

(a) $A_s = 0,32\, Z_{BF}$ cm^2 for $Z_{BF} \leq 83,5$ or

(b) $A_s = 23,2 + \dfrac{Z_{BF}}{25}$ cm^2 for $Z_{BF} > 83,5$

where Z_{BF} is the modulus, in cm^3, of the frame or longitudinal based on the effective length between floors as defined in Ch 2,2.6.

8.6 Additional requirements for watertight floors

8.6.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 8.5.

8.7 Inner bottom plating

8.7.1 Where the inner bottom also acts as the plating of a vehicle deck, stores deck or similar, the requirements of Section 10 are to be complied with.

8.8 Inner bottom longitudinals

8.8.1 Where the double bottom tanks are interconnected with side tanks or cofferdams, the scantling are to be not less than those required for deep tanks, *see* Section 9.

8.8.2 Higher tensile steel inner bottom longitudinals are to be continuous as far as practicable throughout the length of the ship.

8.9 Double bottom tanks

8.9.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in Section 9.

8.10 Margin plates

8.10.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

8.11 Double bottom structure in machinery rooms

8.11.1 The arrangements of the structure in machinery spaces are to be in accordance with Pt 3, Ch 2,6.

8.11.2 The scantlings of floors clear of the main engine seatings, are generally to be as required in 8.4. In way of engine seatings, the floors are to be increased in thickness, *see* 7.5 and Section 13.

8.11.3 Where the double bottom is longitudinally framed and transverse floors are fitted in way of the engine seatings as required by Pt 3, Ch 3,6.6, no additional longitudinal stiffening is required in way of the engines other than the main engine girders, provided that the spacing of girders does not exceed 1,5 times the normal spacing of longitudinals. Where this spacing of girders is exceeded, shell longitudinals are to be fitted. These are to scarf into the longitudinal framing clear of the machinery spaces. The scantlings of the longitudinals are to be determined in accordance with the appropriate requirements for bottom shell longitudinals using a minimum span of 1,3 m.

■ *Section 9* Bulkheads and deep tanks

9.1 General

9.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

9.1.2 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

9.1.3 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The minimum requirements in Section 2 are also to be complied with. Arrangements are to be in accordance with Pt 3, Ch 2,3 and Ch 2.4.

9.1.4 The buckling requirements of Ch 2,4 are also to be satisfied.

9.1.5 The scantlings of bulkheads are to be suitably increased where bulkhead stiffeners support deck girders, transverses or pillars over, *see* Section 12.

9.1.6 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

9.1.7 For ships with an internal blast notation certain bulkheads will require to be strengthened in accordance with Pt 4, Ch 2.

9.2 Deep tank stiffening

9.2.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener, *see* Ch 2,3.

9.3 Gastight bulkheads

9.3.1 Where gastight bulkheads are fitted, in accordance with the requirements of Pt 3, Ch 2,4 the general scantling equations for bulkheads, *see* 3.12 for NS1 ships and 4.6 for NS2 and NS3 ships, are to be complied with using a design pressure of 2 times the test pressure.

9.3.2 In addition the requirements for pillar bulkheads and minimum thickness requirements of Section 2 are to be complied with where appropriate.

9.4 Non-watertight or partial bulkheads

9.4.1 Where a bulkhead is structural but non-watertight, the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames/primary stiffeners in the same position.

9.4.2 Partial bulkheads which are neither watertight nor structural are to have scantlings and arrangements which are suitable for the intended purpose, such bulkheads are outwith the scope of classification.

9.5 Corrugated bulkheads

9.5.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, *s*, is to be taken as *b*, as defined in Fig. 2.2.2 in Chapter 2.

9.5.2 In addition, the section geometric properties of Ch 2,2.9 are to be complied with.

9.5.3 The actual section modulus may be derived in accordance with Ch 2,2.3.1.

9.6 Wash plates

9.6.1 Stiffeners are to be fitted at every frame and efficiently bracketed at top and bottom.

9.6.2 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

9.6.3 The general stiffener requirements are to be in accordance with 3.12 for NS1 ships and 4.6 for NS2 and NS3 ships. However, the section modulus may be 50 per cent of that required if the end connections are bracketed.

9.7 Cofferdams

9.7.1 The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

9.8 Testing

9.8.1 The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted. The testing of tanks is to be in accordance with the naval ship survey procedures manual.

■ *Section 10* Deck structures

10.1 General

10.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

10.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2. Arrangements of structures are to be in accordance with Pt 3, Ch 2,3.7.

10.1.3 The geometric properties of stiffener sections are to be in accordance with Ch 2,2.9. Web depth of secondary longitudinals is in general not to be less than 60 mm.

10.1.4 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with Ch 6,5.

10.1.5 For vehicle decks and areas for aircraft operations, the deck scantlings are to comply with the requirements of Pt 4, Ch 3,2 and Pt 4, Ch 2,10 respectively. Areas of deck subject to blast loads are to comply with the requirements of Pt 4, Ch 2,9.

10.1.6 Decks forming the boundary of a tank are to comply with the requirements for the appropriate deck and are to be additionally examined for compliance with the requirements for deep tank plating.

10.1.7 Decks forming subdivision or watertight internal boundaries are to comply with the requirements for the appropriate deck and are to be additionally examined for compliance with the requirements for watertight plating and stiffening.

10.2 Deck plating

10.2.1 The thickness of the strength deck stringer plate is to be increased by 20 per cent at the ends of superstructures extending out to the ship side, deckhouses, poop and forecastle. The thickness of the strength deck is to be increased by 20 per cent in way of the corners of effective superstructures that are not full width.

10.3 Deck stiffening

10.3.1 Higher tensile steel deck longitudinals where used are to be continuous irrespective of the ship length.

10.3.2 The geometric properties of stiffener sections are to be in accordance with Ch 2,2.9.

10.3.3 The stiffening arrangements and end connection of primary supporting members are to be in accordance with Ch 6,5.

10.3.4 Where the depth of web of a longitudinal girder at the strength deck within $0{,}3L_R$ to $0{,}7L_R$ exceeds:

(a) $55t_w$ for mild steel members

(b) $55t_w\sqrt{k_L}$ for higher tensile steel members

k_L is defined in Ch 5,3.

Additional longitudinal web stiffeners are to be fitted at a spacing not exceeding the value in (a) or (b) as appropriate, with a maximum of $65t_w\sqrt{k_L}$ for higher tensile steel members. In cases where this spacing is exceeded, the web thickness is, in general, to be suitably increased. Alternative proposals will be considered.

10.3.5 Web stiffeners may be flat bars of thickness t_w and depth $0{,}1d_w$, or 50 mm, whichever is greater. Alternative sections of equivalent inertia may be adopted.

10.4 Deck openings

10.4.1 The steel grade for the corner plating or inserts in way of large openings as required by Pt 3, Ch 2,3.7 for both NS1 and NS2 ships is to be in accordance with Table 6.2.1 in Pt 6, Ch 6. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness outside the line of openings with a minimum increase of 4 mm. The increase need not exceed 7 mm.

10.4.2 The steel grade for corner inserts in way of openings for lifts, or cut outs in the deck plating for side doors, etc., is to be Grade E or EH.

10.4.3 Welded attachments close to or on the free edge of the large opening corner plating are to be avoided. The butt welds of corner insert plates to the adjacent deck plating are to be located well clear of butts in the opening coaming or bulkheads.

10.4.4 Where minor deck openings, within $0,3L_R$ to $0,7L_R$, have a total breadth or shadow area breadth in one transverse section that exceeds the limitation given in Pt 6, Ch 4,1.4.11 and 1.4.12, compensation will be required to restore the excess. This is generally to be arranged by increasing the deck plate thickness, but other proposals will be considered.

10.4.5 Plate panels in which openings are cut are to be adequately stiffened, where necessary, against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth.

10.4.6 Minor openings in the strength deck outside the line of major deck openings having a stress concentration factor in excess of 2,4 will require edge reinforcement in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening. For example, elliptical openings having their major axis fore and aft and a ratio of length to breadth not less than 2 to 1 will not normally require edge reinforcement.

10.4.7 Where long, wide openings are arranged on lower decks, it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

10.4.8 Lower deck openings should be kept clear of the corners of major openings and other areas of high stress, so far as possible. Compensation will not, in general, be required unless the total width of openings in any frame space, or between any two transverses, exceeds $15k_s$ per cent of the original effective plating width. The requirements of 10.4.1 also apply to lower deck openings except that:

(a) the thickness of inserts, if required, for the lower deck large opening corners is to be 2,5 mm greater than the deck thickness;

(b) inserts will not generally be required for large opening corners on non-effective decks or platform decks; and

(c) reinforcement will not generally be required for circular openings, provided that the plate panels in which they are situated are otherwise adequately stiffened against compression and shear buckling.

10.5 Sheathing

10.5.1 The requirements for deck sheathing given in 2.4 are to be complied with.

10.6 Decks used as ramps

10.6.1 Where any deck forms a ramp, such decks are to be examined for compliance with the requirements for cargo ramps, *see* Pt 4, Ch 3,5.

Section 11
Superstructures, deckhouses and bulwarks

11.1 General

11.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

11.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with Section 3. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with Section 4. Arrangements of the structure are to be in accordance with the requirements of Pt 3, Ch 2,7.

11.1.3 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirements given in Section 2.

11.1.4 Stiffener sections and geometric properties are to be in accordance with Ch 2,2.9.

11.1.5 For ships with an external blast notation, the superstructure strength is to be in accordance with Pt 4, Ch 2,2.

11.2 Forecastle requirements

11.2.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

11.2.2 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0,75L_R$. No increase is required if the forecastle end bulkhead lies forward of $0,8L_R$. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

11.3 Superstructures formed by extending side structures

11.3.1 The side plating of such superstructures having a length of $0,15L_R$ or greater is to be increased in thickness by 25 per cent at the ends of the structure, and is to be tapered into the sheerstrake, *see* 5.3.1. This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m from the end bulkhead. Proposals for alternative arrangements, including the use of higher tensile steel, will be individually considered.

11.3.2 Where the superstructure contributes to the hull girder strength, the shear capability of the superstructure may need to be verified.

11.4 Mullions

11.4.1 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

11.4.2 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

11.4.3 Where significant shear forces are to be carried by superstructures and deckhouses which have large windows, doors, vents and other openings in their side structures, adequate shear rigidity is to be verified by direct calculation.

11.5 Sheathing

11.5.1 Sheathing arrangements are to comply with the requirements of Ch 3,2.4.

■ *Section 12* Pillars and pillar bulkheads

12.1 Application

12.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3. Arrangements of pillars are to be in accordance with Pt 3, Ch 2,8.

12.2 Determination of span length

12.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by two thirds the depth of the bracket at each end.

12.3 Design loads

12.3.1 The design loading, P_{pi}, to be used in the determination of pillar scantlings is as follows:

$$P_{pi} = S_{gt}\, b_{gt}\, P_c + L_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

L_a = load from pillar or pillars above, assumed zero if there are no pillars over, in kN

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

12.4 Scantling determination

12.4.1 The minimum wall thickness of tubular pillars is to be in accordance with Section 2.

12.4.2 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_{pi}}{\sigma_p} \quad \text{cm}^2$$

where

P_{pi} = design load, in KN, supported by the pillar as determined from 12.3

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_{pi}\,\sigma_o}{1 + 0{,}0051\,\sigma_o\, C_f \left(\dfrac{l_{ep}}{r}\right)^2} \quad \text{N/mm}^2$$

where

f_{pi} = pillar location factor defined in Table 3.12.1

σ_o = specified minimum yield strength of the material, in N/mm^2

C_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_p}{A_p}} \quad \text{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in 12.2.

Table 3.12.1 Pillar location factors

Location	f_{pi}
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting stores equipment and routes	0,50
Supporting accommodation/inner deck	0,75
Supporting deckhouse top	1,00

12.5 Minimum slenderness ratio

12.5.1 The slenderness ratio (l_e/r) of pillars should not in general exceed 1,1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

12.6 Pillars in tanks

12.6.1 The tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 at the tank test pressure.

12.7 Pillar bulkheads

12.7.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from Ch 2,2.2.

12.7.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 12.4 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{pb}\, B_{pb}\, P_c + L_a \quad \text{kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

L_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{pb} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

B_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

12.7.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

12.8 Direct calculations

12.8.1 As an alternative to 12.4, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

12.9 Novel features

12.9.1 Where unusual or novel pillars designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

■ *Section 13*
Machinery and raft seatings

13.1 General

13.1.1 Main and auxiliary engine seatings are to be effectively secured to the hull structure. The scantlings of such seatings are to be adequate for the intended purpose, with due account taken of the gravitational, thrust, torque and vibrating forces together with the load increases resulting from sea motions and shock which may be imposed upon them.

13.1.2 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

13.1.3 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and are to be adequately supported by transverse floors or brackets. The webs of the longitudinal girders are to be welded to the bottom shell plating.

13.1.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Half floors, transverse brackets or hanging brackets will in general be required under the top plate in way of holding down bolts.

13.1.5 Where rafts are proposed for supporting the main and auxiliary engines the arrangements of such rafts are to be in accordance with Vol 2, Pt 1, Ch 2.

13.1.6 Welding in way of all machinery seating is be double continuous and where appropriate full penetration.

13.1.7 Large areas of unstiffened flat plate are to be avoided.

13.1.8 The number openings of lightening holes in the seating structure are to be kept to the minimum necessary for access essential for maintenance, etc. Lightening holes are to be as small as practicable and are in no case to be greater than one half of the corresponding dimension of the plate in which they are positioned. Lightening holes with dimensions which are in excess of one third the corresponding dimension of the plate in which they are positioned are to suitably edge stiffened by spigots or other equivalent means.

13.1.9 Machinery seatings are additionally to be examined for compliance with the bottom stiffening requirements as appropriate for their location, with due account taken of both local and global loadings.

13.2 Seats for oil engines

13.2.1 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces.

13.2.2 In the case of higher power oil engines or turbine installations the seatings should generally be integral with the bottom structure. The tank top plating in way of the engine foundation plate or the turbine gear case and the thrust bearing should be substantially increased in thickness, *see* Fig. 3.13.1, Type 1.

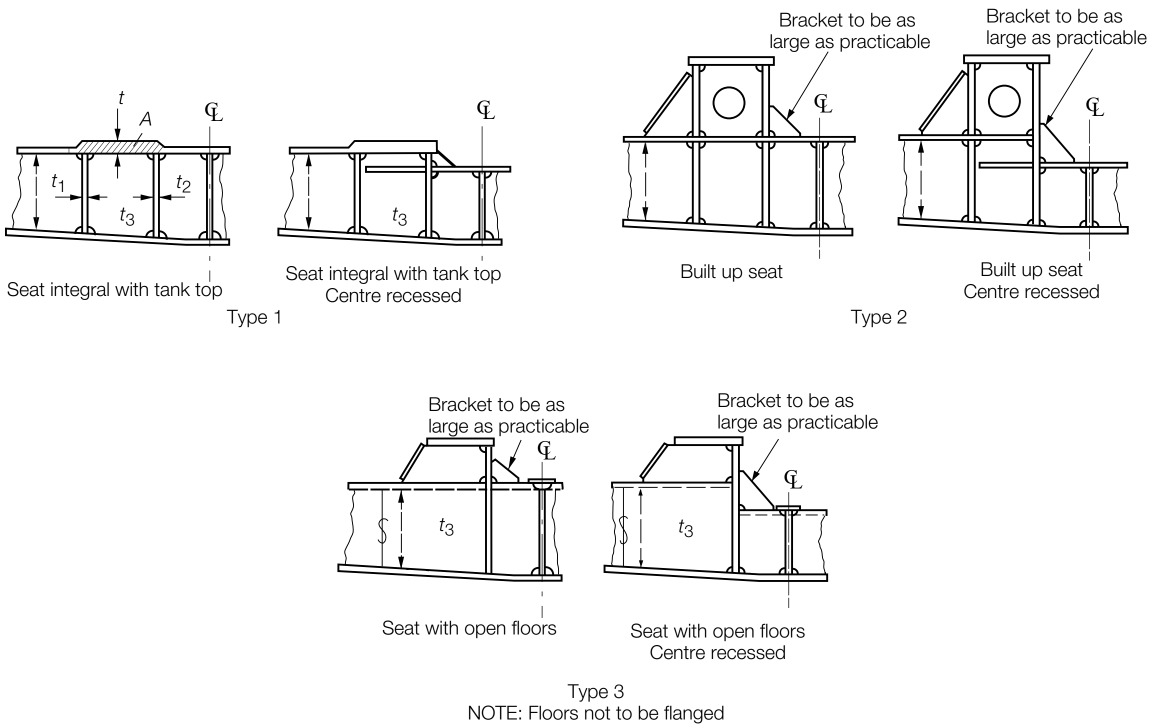


Fig. 3.13.1 Machinery and raft seatings

13.2.3 If the main machinery is supported on seatings of Type 2 as shown in Fig. 3.13.1, these are to be so designed that they distribute the forces from the engine as uniformly as possible into the supporting structure. Longitudinal members supporting the seating are to be arranged in line with girders in the double bottom, and adequate transverse stiffening is to be arranged in line with floors, *see* Fig. 3.13.1, Type 2.

13.2.4 In ships having open floors in the machinery space the seatings are generally to be arranged above the level of the top of floors and securely bracketed to them, *see* Fig. 3.13.1, Type 3.

13.3 Seats for turbines

13.3.1 Seats are to be so designed as to provide effective support for the turbines and ensure their proper alignment with the gearing, and (where applicable) allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

13.4 Seats for boilers

13.4.1 Boiler seats are to be of substantial construction and efficiently supported by transverse and horizontal brackets. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at boiler flats. Suitable allowance is to be made in the design of the supporting structure for the variation in loading due to thermal expansion effects.

13.5 Seats for auxiliary machinery

13.5.1 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

■ *Section 14* Strengthening for bottom slamming

14.1 General

14.1.1 This section may be used to determine the additional scantlings for strengthening in respect of the bottom structure forward for NS1 and NS2 type ships.

14.1.2 The additional scantlings for strengthening in respect of the bottom structure forward for NS3 type ships will be specially considered on the basis of this Section.

14.2 Strengthening of bottom forward

14.2.1 The bottom forward is to be additionally strengthened where the ship has a draught forward of less than $0{,}045L_R$ in any operational loading condition. This minimum draught, T_{FB}, *see* 14.2.7, is to be indicated on the shell expansion plan, the plan showing the internal strengthening, the Loading Manual and loading instrument, where fitted.

14.2.2 The requirements for the additional strengthening apply to ships where L_R is greater than 65 m.

14.2.3 The scantling requirements outside the areas which have been strengthened for bottom slamming are to be suitably tapered to maintain adequate continuity of strength in both longitudinal and transverse directions.

14.2.4 The scantling requirements for the additional strengthening are given in Table 3.14.1, or may be obtained by direct calculation. Where T_{FB} is less than $0{,}01L_R$, the additional strengthening is to be specially considered.

14.2.5 Bottom longitudinals are to pass through and be supported by the webs of primary members. The vertical web stiffeners are to be connected to the bottom longitudinals. The cross-sectional area of the connections is to comply with the requirements given in Table 3.14.1.

14.2.6 The scantlings required by this Section must in no case be less than those required by other Sections in Chapter 3.

14.2.7 For NS1 ships with a block coefficient, C_b, greater than 0,6, the equivalent slamming pressure expressed as a head of water, h_s, is to be obtained from Fig. 3.14.1, where h_{max} is calculated from the following expressions:

$$65 < L_R \leq 169 \text{ m}, \quad h_{max} = 10\sqrt{L_R}\, F \text{ m}$$

$$L_R > 169 \text{ m}, \quad h_{max} = 130F \text{ m}$$

where

$$F = 5{,}95 - 10{,}5\left(\frac{T_{FB}}{L_R}\right)^{0,2}$$

T_{FB} = is the minimum draft at the location under consideration

L_R as defined in Pt 3, Ch 1,5.2.

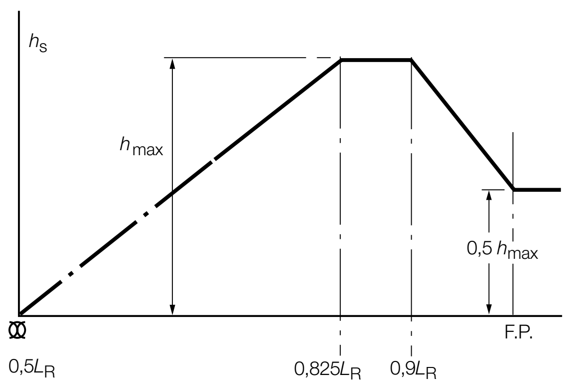


Fig. 3.14.1 Pressure heads

14.2.8 For NSI ships where $C_b < 0{,}6$ and for NS2 and NS3 ships, the bottom impact pressure is to be derived in accordance with the following. The equivalent slamming pressure head, h_s, is to be derived from the instantaneous bottom impact pressure IP_{bi}, *see* Pt 5, Ch 3,4.2.

$$h_s = \frac{f_{DLF}\, IP_{bi}}{10} \text{ m}$$

where

f_{DLF} is the dynamic load derived from the plating or the stiffener/plate combination as appropriate, *see* Ch 2,6. The duration t_1 is given as follows:

$$t_1 = 2t_r \text{ seconds}$$

where

t_r is the rise time given in Pt 5, Ch 3,4.2.

Table 3.14.1 Additional strengthening of bottom forward (*see continuation*)

Item	Requirements	
(1) Longitudinally framed bottom shell plating (including keel) (*see* Notes 1 and 2)	$t = 0{,}003s\, f \sqrt{h_S\, k_S}$	
(2) Bottom longitudinals – other than flat bars	$\frac{d_W}{t_W} \leq 55 \sqrt{k_S}$ $\frac{d_W\, t_W}{100} \geq 0{,}00033\, k_S\, h_S\, s\, c \left(S - \frac{s}{2000}\right)$ cm^2 $Z \geq 6{,}8 \times 10^{-6}\, h_S\, s\, k_S \left[(17{,}5\, l_S)^2 - (0{,}01s)^2 + d_W\, c \left(S - \frac{s}{2000}\right)\right]$ cm^3 $\frac{(A_1\, \tau + \alpha)}{p} \times 10^{-1} \geq 1$ $A_W \geq 0{,}84\, A_1$	
(3) Bottom longitudinals – flat bars	Will be specially considered	
(4) Primary structure in way of single bottoms	Transverse framing	Longitudinal framing
	(a) Centreline girder: Scantlings as required by Table 3.3.12 as appropriate, except that in determining Z in way of a deep tank forward of $0{,}8L_R$ the value of h_5 is to be increased by the following percentages: where $T_{FB} \leq 0{,}03L_2$, 30 per cent where $T_{FB} \geq 0{,}04L_2$, 0 per pent The increase in h_5 for intermediate values of T_{FB} to be obtained by interpolation (b) Floors: Scantlings as required by Table 3.3.12 as appropriate, except that in way of dry spaces the minimum face area is to be increased by the following percentages: where $T_{FB} \leq 0{,}03L_2$, 50 per cent where $T_{FB} \geq 0{,}04L_2$, 0 per pent The increase of minimum face area for intermediate values of T_{FB} to be obtained by interpolation (c) Side girders: Arrangement and scantlings as required by Table 3.3.12 as appropriate, with the addition of intermediate half-height girders or equivalent fore and aft stiffening	(a) Ships having one or more longitudinal bulkheads: (i) Centreline girder Scantlings as required by Table 3.3.12 as appropriate (ii) Bottom transverses Maximum spacing as for midships region, scantlings as required by Section 2, as appropriate (iii) For horizontally stiffened longitudinal bulkheads and girders the depth to thickness ratio of the panel attached to the bottom shell plate is not to exceed $55 \sqrt{k_S}$ (iv) Where T_{FB}, $<0{,}025L_2$ the scantlings and arrangements will receive individual consideration (b) Other ship arrangements will receive individual consideration
(5) Primary structure in way of double bottoms (see Note 3)	(a) Plate floors: Maximum spacing, every frame Scantlings as required by Section 2 (b) Centreline and side girders: Maximum spacing, $0{,}003s_F$ m Scantlings as required by Section 2 (c) Intermediate half-height girders to be arranged midway between side girders: Scantlings as required for non watertight side girders by Section 2	(a) Plate floors: Maximum spacing: $0{,}002s_F$ m for $T_{FB} < 0{,}04L_2$ $0{,}003s_F$ m for $T_{FB} \geq 0{,}04L_2$ but not to exceed that required by Table 3.3.12 as appropriate (b) Centreline and side girders: Maximum spacing: $0{,}003s_L$ m for $T_{FB} < 0{,}04L_2$ $0{,}004s_L$ m for $T_{FB} \geq 0{,}04L_2$ but not to exceed that required by Table 3.3.12, as appropriate Scantlings as required by Table 3.3.12, as appropriate
(6) Primary structure in way of double bottoms supported by longitudinal bulkheads	—	The scantlings and arrangements will receive individual consideration on the basis of direct calculations using, if necessary, a suitably defined two-dimensional grillage model

Table 3.14.1 Additional strengthening of bottomforward (*conclusion*)

Symbols

L_R, T as defined in Pt 3, Ch 1,5.2
L_2, S, s, k_s as defined in 3.2.1
c = 1,0 for $S \leq 2,5$ m
= $(0,87 + 0,16S)\, c_1$ for $S > 2,5$ m
c_1 = 1,0 for $S \leq 1,0$ m
= $(1,14 - 0,14S)$ for 1,0 m < $S \leq 4,0$ m
= $\frac{2,32}{S}$ for $S > 4,0$ m
d_w = web depth, in mm, *see* Fig. 2.2.1 in Chapter 2
f = $\left(1,1 - \frac{s}{2500S}\right)$ but not greater than 1,0
h_s = equivalent slamming pressure, in metres, obtained from 14.2.7 or 14.2.8
l_s = l_e, in metres, as defined in Ch 2,2.6 where in way of a double bottom
= S, in metres, where in way of a single bottom
p = $9,81 h_s\, s c_1 \left[S - \frac{s}{2500}\right] \times 10^{-3}$ kN
s_F = spacing of transverse frames, in mm, for longitudinally framed side and bottom construction s_F may be taken as s_L
s_L = spacing of bottom longitudinals, in mm
t_w = web thickness, in mm
A_f = cross-sectional area of primary member web stiffener, in cm^2
A_{fc} = effective area of primary member web stiffener in way of butted end connection to the longitudinal, in cm^2
A_L = area of weld of lapped connection, in cm^2, calculated as total length of weld, in cm x throat thickness, in cm
A_w = area of weld of lug and web connection to the longitudinal, in cm^2, calculated as total length of weld in cm x throat thickness, in cm
A_1 = effective total cross-sectional area of the lug and web connection to the longitudinal, in cm^2
T_{FB} = draught, in metres, at the F.P., as defined in 14.2.1
α = $A_f \bar{\sigma}$ for the web stiffeners
= $A_{fc} \bar{\sigma}$ for a butted connection to the longitudinals
= $A_L \bar{\tau}$ for a lapped connection
$\bar{\sigma}$ = permissible direct stress, in N/mm^2, given in Table 3.14.2
$\bar{\tau}$ = permissible shear stress, in N/mm^2, given in Table 3.14.2

NOTES
1. If intermediate stiffening is fitted the thickness of the bottom shell plating may be 80 per cent of that required by (1) but is to be not less than the normal taper thickness.
2. For transverse framing the bottom shell plating is to be specially considered.
3. Particular care is to be taken to limit the size and number of openings in way of the ends of floors or girders or to fit suitable reinforcement where such openings are essential.
4. The welding requirements of Ch 6,3 are also to be complied with.

Table 3.14.2 Permissible stresses

Item		Direct stress, $\bar{\sigma}$ in N/mm^2 *see* Note	Shear stress, $\bar{\tau}$ in N/mm^2
Primary member web stiffener on area A_f	(a) Flat bars (*see* Note)	$\frac{10,3}{k_s}\left[33 - \frac{d}{t\sqrt{k_s}}\right]$	–
	(b) Bulb plates (*see* Note)	$\frac{8,6}{k_s}\left[40 - \frac{d}{\left(\frac{100A_f}{d} - \frac{t}{6}\right)\sqrt{k_s}}\right]$	–
	(c) Inverted angles	$\frac{220}{k_s}$	–
Primary member web stiffener on area A_{fc}		$\frac{245}{k_s}$	–
Primary member web stiffener lapped to secondary member on area A_L		–	$\frac{167}{k_s}$
Lug or web connection on area A_1	Single	–	$\frac{124}{k_s}$
	Double	–	$\frac{141}{k_s}$

Symbols

A_f, A_L, A_1 as defined in Table 3.14.1
d = stiffener depth, in mm
k_s = as defined in 3.2.1
t = stiffener web thickness, in mm

NOTE
$\bar{\sigma}$ to be taken not greater than $\frac{220}{k_s}$.

■ *Section 15* Strengthening for wave impact loads above waterline

15.1 General

15.1.1 This Section may be used to determine the required scantlings for strengthening against bow flare slamming for NS1 and NS2 type ships and for wave impacts on the shell envelope. Direct calculations may also be used to determine the required scantling.

15.1.2 The required scantlings for strengthening against wave impact loads for NS3 type ships will be specially considered on the basis of this Section.

15.1.3 The scantling requirements contained in this section are based on no permanent set of plating. If acceptable to the Owner, special consideration will be given to an alternative plating performance specification. Areas designed in accordance with an alternative performance specification are to be clearly marked on the plans. Direct calculations may be used to determine the required scantlings.

15.2 Strengthening against bow flare wave impacts

15.2.1 The shell envelope above the summer load waterline is to be strengthened against bow flare wave impact pressures. The strengthening is to extend vertically to the uppermost deck level, including the forecastle deck, if fitted.

15.2.2 The equivalent bow flare wave impact head, h_s, is to be taken as:

$$h_s = \frac{f_{DLF}\, IP_{bf}}{10} \text{ m}$$

where

IP_{bf} is the bow flare or above waterline wave impact pressure, *see* Pt 5, Ch 3,4.3.

f_{DLF} is the dynamic load factor derived from the plating or the stiffener/plate combination as appropriate, *see* Ch 2,6. The duration, t_1, is given as follows:

t_1 = $2t_r$ seconds

where

t_r is the rise time given in Pt 5, Ch 3,4.3.

15.2.3 The thickness of the side shell is to be not less than:

$$t = 3{,}2 s_c \sqrt{k_s\, h_s}\, C_R \times 10^{-2} \text{ mm}$$

where

s_c = spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 3.15.1

h_s = bow flare wave impact head, in metres, as defined in 15.2.2

C_R = panel ratio factor

= $\left(\dfrac{l}{s_c}\right)^{0{,}41}$ but is not to be taken less than 0,06 or greater than 0,1

l = overall panel length, in metres, measured along a chord between the primary members

k_s = as defined in 3.2.1.

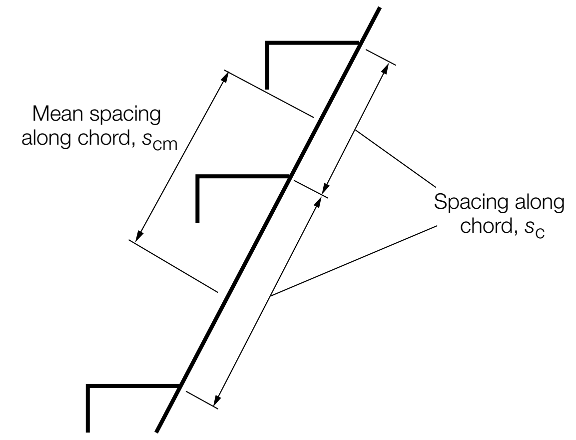


Fig. 3.15.1
Chord spacing and mean chord spacing for secondary members

15.2.4 The scantlings of secondary stiffeners are not to be less than:

(a) Section modulus of secondary stiffeners:

$$Z = \frac{h_s\, s_{cm}\, k_s\, l_e^2}{483} \text{ cm}^3$$

where

h_s = wave impact head, in metres, as defined in 15.2.2

s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 3.15.1

Other symbols are as defined in 15.2.3 and 15.2.5.

(b) Web area of secondary stiffeners

$$A = 3{,}7 s_{cm}\, k\, h_s \left(l_e - \frac{s_{cm}}{2000}\right) \times 10^{-4} \text{ cm}^2$$

where

s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in Fig. 3.15.1

h_s = wave impact head, in metres, as defined in 4.3.2

Other symbols are as defined in Ch 2,1.

15.2.5 The scantlings of primary members are not to be less than:

(a) Section modulus of primary members

$Z = 2\gamma_Z\, k\, h_s\, q\, \nu\, l_e^2$ cm^3

(b) Web area of primary members

$A = 0{,}2\gamma_A\, k\, h_s\, q\, \nu\, l_e$ cm^2

where

h_s = bow flare wave impact head, in metres, as defined in 15.2.2

and

γ_A and γ_Z are strength factors dependant on the load position

for $q < 1$ $\gamma_A = q^3 - 2q^2 + 2$ and $\gamma_Z = 3q^3 - 8q^2 + 6q$

for $q = 1$ $\gamma_A = 1$ and $\gamma_Z = 1$

$q = \dfrac{u}{l_e}$ but ≤ 1

for web frames:

u is the minimum of g_{bfv} or l_e

ν is the minimum of g_{bfh} or S_{cm}

for primary stringers:

u is the minimum of g_{bfh} or l_e

ν is the minimum of g_{bfv} or S_{cm}

where

l_e is the effective length of the primary member, in m

S_{cm} is the mean spacing between primary members along the plating, in m, *see* Fig. 3.15.2

g_{bfv} and g_{bfh} are defined in Pt 5, Ch 3,4.3.3

Other symbols are as defined in Ch 2,1.

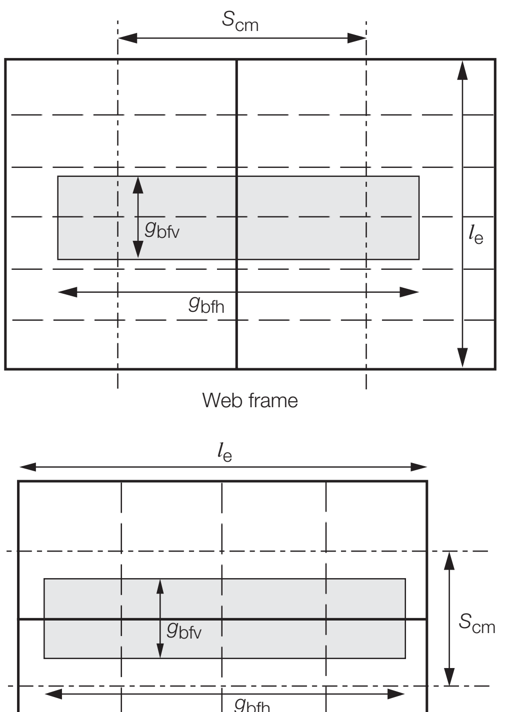


Fig. 3.15.2
Mean spacing between primary members, S_{cm}, and the extents of the bow flare wave impact pressure, g_{bfh} and g_{bfv}

15.2.6 For primary members with cut-outs for the passage of secondary stiffeners, and which may have web stiffeners connected to the secondary stiffener, buckling checks are to be carried out to ensure that the primary member web plating and web stiffener will not buckle under the design load. The buckling procedure to be followed is given in Table 3.15.1. Where the web stiffener is fitted with a bracket, the buckling capability of the web stiffener is way of the cut-out is to take into account the bracket. Where no web stiffener is fitted, the buckling capability of the primary member web plating is to be checked for the total load transmitted to the connection.

15.2.7 The structural scantlings required in areas strengthened against bow flare wave impact are to be tapered to meet the normal shell envelope requirements.

15.2.8 Where the stiffener web is not perpendicular to the plating, tripping brackets may need to be fitted in order to obtain adequate lateral stability.

15.2.9 For stiffeners and primary structure, where the angle between the stiffener web and the plating is less than 70°, the effective section modulus and shear area are to take account of the non-perpendicularity.

15.2.10 The side structure scantlings required by this Section must in no case be taken less than those required by other Sections of Chapter 3.

15.3 Strengthening against wave impact loads

15.3.1 The requirements of 15.2 are to be applied to areas of plating which are liable to be subjected to wave impact loads; for example, bottom plating of wide transom sterns, undersides of sponsons for aircraft lifts.

Table 3.15.1 Buckling procedure for primary member web plating and web stiffener

Steps	Members	
	Primary member web plating	Primary member web stiffener
Determination of the design compressive stress, σ_a, N/mm^2 (kgf/mm^2)	$\sigma_a = \dfrac{1000 P_w}{A_w}$	$\sigma_a = \dfrac{1000 P_s}{A_s}$
Determination of the elastic critical buckling stress, σ_e, in compression, N/mm^2 (kgf/mm^2)	$\sigma_e = \dfrac{9{,}87 E\, I_w}{l_w^2 A_w}$	$\sigma_e = \dfrac{9{,}87 E\, I_s}{l_s^2 A_s}$
Determination of the corrected critical buckling stress, σ_{cr}, in compression, N/mm^2 (kgf/mm^2)	$\sigma_{cr} = \sigma_o \left(1 - \dfrac{\sigma_o}{\sigma_e}\right)$ where $\sigma_e > \dfrac{\sigma_o}{2}$ $\sigma_{cr} = \sigma_e$ where $\sigma_e \leq \dfrac{\sigma_o}{2}$	
Requirement	$\sigma_{cr} \geq \sigma_a$	
Symbols		

b_w, b_s, l_w, and l_s are dimensions, in mm, as shown in Fig. 3.15.3

h_s = equivalent bow flare slamming head, in metres, as defined in 15.2.2
s_{cm} = mean spacing of secondary stiffeners, in mm, as defined in 15.2.4
t_s = thickness of primary member web stiffener, in mm
t_w = thickness of primary member web plating, in mm
A_w = $b_w t_w$ mm^2
A_s = $b_s t_s$ mm^2
E = modulus of elasticity, in N/mm^2
= 206000 N/mm^2 for steel

$I_s = \dfrac{b_s t_s^3}{12}$ mm^4

$I_w = \dfrac{b_w t_w^3}{12}$ mm^4

P = total load transmitted to the connection
= $10{,}06\, S_{cm}\, s_{cm}\, h_s \times 10^{-3}$ kN
P_s = load transmitted through the primary member web stiffener, in kN, to be determined from $P_2 = P - P_1$, in kN, or by direct calculations. Where P_1 = pressure transmitted through collar arrangement and P = total load transmitted to the primary member
P_w = load transmitted through the primary member web plating, in kN
= $P - P_s$, or by direct calculations
S_{cm} = mean spacing of primary members, in metres, as defined in 15.2.5
σ_o = specified minimum yield stress, in N/mm^2

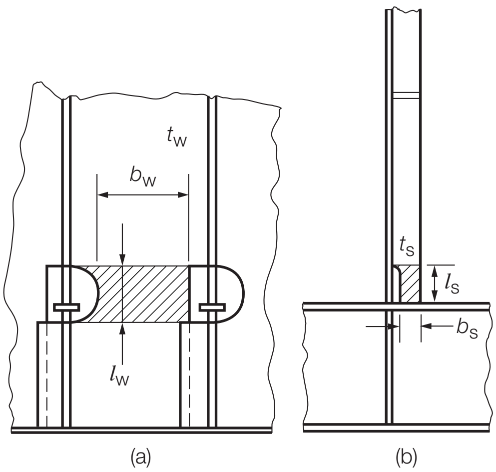


Fig. 3.15.3
Dimensions of critical areas of (a) primary member web plating and (b) primary member web stiffener

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength are contained within this Chapter.

1.1.2 This Chapter contains sections detailing the analysis requirements for the following topics:

- Hull girder strength.
- Extreme strength assessment.
- Residual strength assessment.

1.1.3 **Section 2, Hull girder strength.** This Section specifies the hull girder strength requirements based on the conventional elastic design and buckling analyses. All ships are to comply fully with the requirements of this Section.

1.1.4 **Section 3, Extreme strength assessment.** This Section specifies the requirements for the assessment of the extreme hull girder strength to withstand wave loads that have a low probability of occurring during the life of the ship. This is an optional assessment and ships which comply with the extreme strength requirements can apply for the notation **ESA1** or **ESA2**, *see* Pt 1, Ch 2,3.6.1.

1.1.5 **Section 4, Residual strength assessment.** This Section specifies the requirements for the assessment of the residual hull girder strength after the ship has sustained structural damage. This is an optional assessment and ships which comply with the residual strength requirements can apply for the notation **RSA1**, **RSA2** or **RSA3**, *see* Pt 1, Ch 2,3.6.1.

1.2 Hull girder strength notations

1.2.1 The following notations are available for all ships with regard to global hull girder strength aspects:

- **ESA1**, **ESA2** Extreme strength assessment.
- **RSA1**, **RSA2**, **RSA3** Residual strength assessment.

A distinction is made between levels of performance and levels of assessment; the numeral in the notation reflects the level of assessment. Levels of performance are denoted by the letters A, B, C for collision or grounding damage and numerals I, II and III for damage from military threats and are confidential to the Owner. *See* 4.2 for non military threats and Vol 1, Pt 4, Ch 2,7 for military threats.

1.2.2 The performance of the ship with respect to extreme hull girder strength aspects may be evaluated at two levels. **ESA1**, the lowest level offers a basic assessment of the ship's capability. **ESA2**, the higher level is a much more rigorous assessment of the hull's capability to withstand extreme sea states.

1.2.3 It is recommended that ships of groups NS1 and NS2 should comply with **ESA1**. However, it is the responsibility of the Owner to specify the level of extreme strength assessment required.

1.2.4 The extreme strength assessment level adopted must reflect the performance level required by other notations.

1.2.5 The two levels of assessment available for the extreme strength assessment notation are summarised as follows:

ESA1 This uses elastic theory, based on the section moduli and area, and determination of the buckling strength to resist the global hull girder loads. The assessment is to be made at a minimum of three locations.

ESA2 Uses a '2D' ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactory compared to the design bending moments in both hogging and sagging. This will require assessment using ultimate strength calculations at all critical longitudinal locations.

1.2.6 The performance of the ship with respect to residual strength aspects may be evaluated at several levels. The lowest level offers a basic assessment of the ship's capability to survive. Higher residual strength levels are designed to show that the ship has an improved performance with respect to hull's capability to withstand increased damage extents and scenarios.

1.2.7 Three assessment and performance levels are available for the residual strength assessment notation. **RSA1**, the assessment Level 1 residual strength assessment and performance level A is recommended as a minimum for all ships of groups **NS1** and **NS2**. However, it is the responsibility of the Owner to specify the level of residual strength assessment required.

1.2.8 The residual strength assessment level adopted must reflect the performance level required by other notations.

1.2.9 The three levels of assessment available for the extreme strength assessment notation are summarised as follows:

RSA1 This uses elastic theory, based on the remaining section moduli and area after damage, and determination of the buckling strength to resist the global hull girder loads. The assessment is to be made at a minimum of three critical sections.

RSA2 Uses a '2D' ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactorily compared to the design bending moments in both hogging and sagging. The assessment is to be made at a minimum of three critical sections.

RSA3 Uses a '3D' definition of a section of the hull girder and relies on geometric and material failure criteria implicit in the chosen finite element code. It could also include coupled Euler-Lagrange formulations to specifically account for internal and external blast effects, UNDEX shock and whipping.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the ship, in metres

B = moulded breadth of ship, *see* Pt 3, Ch 1,5.2, in metres

σ_o = specified minimum yield strength of the material, in N/mm^2

τ_o = $\sigma_o/\sqrt{3}$

f_{hts} = higher tensile steel correction factor, *see* Ch 5,1.3, Table 5.1.1.

1.3.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck, the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of ships with a raised quarterdeck, the strength deck is stepped as shown in Fig. 4.1.1. Adequate provision should be made for the transfer of load between the stepped decks. The length of overlap required is to be taken as 4 times the deck height.

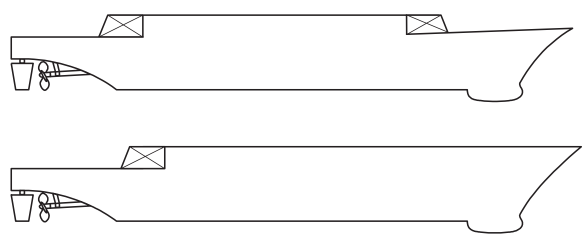


Fig. 4.1.1 Strength deck

1.4 Calculation of hull section modulus

1.4.1 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

1.4.2 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.4.3 In general, short superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the ship. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations, *see also* 2.5.

1.4.4 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus, Z. The lever is to be taken to a position corresponding to the height of the longitudinal member above the moulded deck line at side amidships. Each such case will be individually considered.

1.4.5 Adequate transition arrangements are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.4.6 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within 0,4L_R amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L_R part, bearing in mind the desire not to inhibit the ship's loading and operational flexibility.

1.4.7 Structural material which is longitudinally continuous but which is not considered to be fully effective for longitudinal strength purposes will need to be specially considered. The global longitudinal strength assessment must take into account the presence of such material when it can be considered effective. The consequences of failure of such structural material and subsequent redistribution of stresses into or additional loads imposed on the remaining structure must be considered.

1.4.8 In particular, all longitudinally continuous material will be fully effective in tension whereas this may be not be so in compression due to a low buckling capability. In this case, it may be necessary to derive and apply different hull girder section moduli to the hogging and sagging bending moment cases.

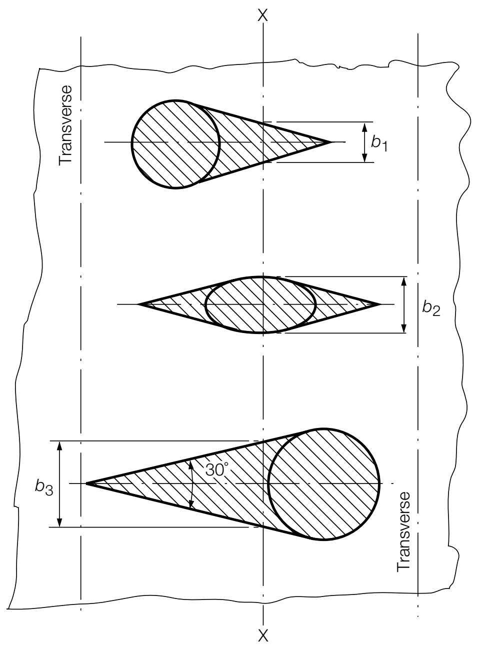
1.4.9 Openings in decks, longitudinal bulkheads and other longitudinal effective material having a length in the fore and aft directions exceeding 0,1B m or 2,5 m or a breadth exceeding 1,2 m or 0,04B m, whichever is the lesser, are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.10 Openings smaller than stated in 1.4.9, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths, *see* 1.4.13, in one transverse section does reduce the section modulus at deck or bottom by more than 3 per cent.

1.4.11 The expression 0,06 (B_1 – Σb_1), where B_1 equals the breadth of the ship at the section considered and Σb_1 equals the sum of breadths of deductible openings, may be used for deck openings in lieu of the 3 per cent limitation of reduction of section modulus in 1.4.10.

1.4.12 Where a large number of openings are proposed in any transverse space, special consideration will be required.

1.4.13 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 4.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings
$\Sigma b_o = b_1 + b_2 + b_3$ at position xx

Fig. 4.1.2 Isolated openings

1.4.14 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.15 Openings are considered isolated if they are spaced more than 1 m apart.

1.4.16 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the global section modulus at deck or keel is reduced by no more than 0,5 per cent.

1.5 General

1.5.1 The Level 1 assessment procedures specified in Lloyd's Register's (hereinafter referred to as 'LR') Structural Detail Design Guide for fatigue design assessment, **FDA**, are to be generally applied to the construction details of all ships.

1.6 Direct calculations

1.6.1 Direct calculations using finite element analysis may be necessary for ships with complicated longitudinal structural arrangements such as ships:
- of novel design;
- with significant discontinuous longitudinal material;
- with large deck openings, or where warping stresses in excess of 14,7 N/mm^2 are likely to occur;
- with large openings in the side shell, especially in way of the sheerstrake.

■ *Section 2*
Hull girder strength

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all ships with a Rule length, L_R, exceeding 50 m and are to cover the range of operating conditions proposed in order to determine the required hull girder strength. The still water, wave and dynamic bending moments and shear forces are to be calculated in accordance with the requirements of Pt 5, Ch 4.

2.1.2 For ships of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However, longitudinal strength calculations may be required by LR, dependent upon the form, constructional arrangement and proposed loading.

2.2 Bending strength

2.2.1 The effective geometric properties of all critical transverse sections along the length of the ship are to be calculated directly from the dimensions of the section using only effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction, *see* 1.4.

2.2.2 Where higher tensile is fitted to satisfy global strength requirements, the extent of higher tensile steel is to be as specified in Ch 2,1.6.3. Where a mix of steel grades is used for plating and associated stiffeners, then the lower of the steel grades is to be used for the derivation of the permissible stresses, *see* 2.2.3.

2.2.3 The longitudinal strength of the ship is to satisfy the following criteria for the hogging and sagging conditions:

$$\sigma_B < \sigma_p$$
$$\sigma_D < \sigma_p$$
$$\sigma_{ws} < f_{\sigma ws}\, \sigma_{o(MS)}$$

where

σ_p = maximum permissible hull vertical bending stress, in N/mm^2

σ_p = $f_{\sigma hg}\, f_{hts}\, \sigma_o$

$f_{\sigma hg}$ = limiting hull bending stress coefficient, derived as follows:
(i) from $0,3L_R$ to $0,7L_R$
$f_{\sigma hg} = 0,75$
(ii) for continuous longitudinal structural members aft of $0,3L_R$ and forward of $0,7L_R$
$f_{\sigma hg} = 0,319 + 2,311\ x/L_R - 2,974\ (x/L_R)^2$

where

x = the distance, in metres, from the F.P. for locations within the forward end of L_R and from the A.P. for locations within the aft end of L_R

$f_{\sigma ws}$ = 1,2, limiting working stress coefficient
NOTE, the σ_{ws} criterion may be relaxed if it can be demonstrated that either:
(i) a continuous fatigue control monitoring system is to be adopted for the in-service life of the ship
(ii) a fatigue design assessment procedure is applied which demonstrates that a higher limiting working stress coefficient, $f_{\sigma ws}$, may be applied

$\sigma_{o(MS)}$ = specified yield stress, in N/mm^2, for mild steel

σ_B, σ_D and σ_{ws} are given in Table 4.2.1

f_{hts} and σ_o are defined in 1.3.1.

Table 4.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck, *see* Note 1	$\sigma_D = \dfrac{M_R}{1000Z_D}$
Hull girder bending stress at keel, *see* Note 1	$\sigma_B = \dfrac{M_R}{1000Z_B}$
Hull girder bending stress range, *see* Note 2	$\sigma_{ws} = \dfrac{M_{WHog} - M_{WSag}}{1000Z_D}$
Symbols	
M_R = Rule bending moment, in kNm, given in Pt 5, Ch 4,3.10 M_{WHog} = hogging value of M_W, in kNm, given in Pt 5, Ch 4,3.3 M_{WSag} = sagging value of M_W, in kNm, given in Pt 5, Ch 4,3.3 Z_D = actual section modulus at deck, in m^3 Z_B = actual section modulus at keel, in m^3	
NOTES 1. The hogging and sagging bending moments are to be considered. 2. The stress range at the keel or other longitudinally effective material should be used if it is greater than the stress range at the strength deck.	

2.2.4 Special consideration will be given to increasing the permissible stress outside $0,3L_R$ to $0,7L_R$ provided that sufficient buckling checks are carried out.

2.2.5 The requirements for ships of special or unusual design and for special operations will be individually considered.

2.2.6 Where different grades of steel are used then it should be ensured that the design stress in each structural member is less than the permissible hull vertical bending stress, i.e.

$$\sigma_{hg} < \sigma_p$$

where

σ_{hg} is given in 2.2.7
σ_p is given in 2.2.3.

2.2.7 The design stress due to hull girder bending, σ_{hg}, for each structural member is given by

$$\sigma_{hg} = \left(\frac{M_R}{1000Z_i}\right) \text{ N/mm}^2$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_R is given in Table 4.2.1.

2.3 Shear strength

2.3.1 The shear strength of the all ships is to satisfy the requirements given in this Section.

2.3.2 For ships with large openings in the side shell and or a complex arrangement of longitudinal bulkheads and decks is proposed, shear flow calculations or direct calculation may be required.

2.3.3 Where shear flow calculation procedures other than those available within ShipRight are employed, the requirements of Ch 3,1.4 are to be complied with.

2.3.4 The assessment of still water shear stresses is to take into consideration the effectiveness of the following:

- continuous superstructures;
- the sizes and arrangements of window and door openings;
- access openings or cut-outs in side shell, longitudinal bulkheads, etc.

2.3.5 The shear strength of the ship at any position along the length is to satisfy the following criterion:

$$\frac{|Q_R|\,A_z}{I\,\delta_o} \leq \tau_p$$

where

δ_o is to be taken as the minimum value of δ_i, and

τ_p = maximum permissible shear stress, in N/mm^2
= $f_{\tau\,hg}\,\tau_o$

$f_{\tau\,hg}$ = $0,75f_{hts}$, limiting hull shear stress coefficient

Q_R = Rule shear force, in kN, determined from Pt 5, Ch 4,3.10

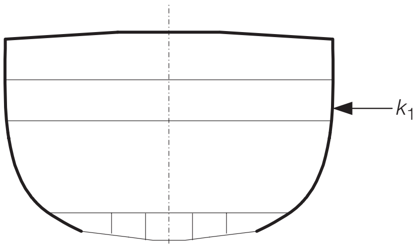
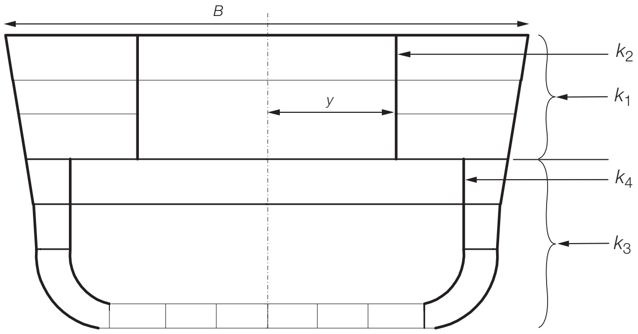
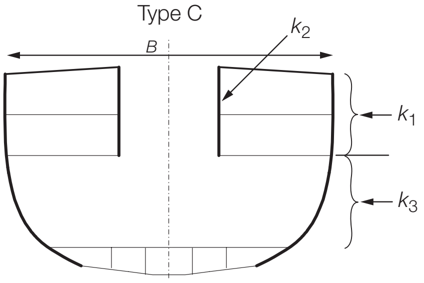
I = the inertia of the hull about the transverse neutral axis at the section concerned, in m^4

A_z = the first moment of area of the longitudinal members about the neutral axis, in m^3
Only longitudinally effective members that lie between the vertical level being considered and the vertical extremity are to be included

$$\delta_i = \frac{t_i}{k_i}$$

i = structural member index for the hull configuration under consideration, *see* Table 4.2.2

Table 4.2.2 k_j factors

Hull configuration	*ki* factors
Type A 	Member 1 $k_1 = 0{,}5$
Type B 	Member 1 $k_1 = 0{,}04\dfrac{A_1}{A_2} + 0{,}2\left(\dfrac{y}{B} - 0{,}19\right) + 0{,}25$ Member 2 $k_2 = -0{,}04\dfrac{A_1}{A_2} - 0{,}2\left(\dfrac{y}{B} - 0{,}19\right) + 0{,}25$ Member 3 $k_3 = -0{,}01\dfrac{A_3}{A_4} + 0{,}25$ Member 4 $k_4 = 0{,}01\dfrac{A_3}{A_4} + 0{,}25$
Type C 	Member 1 $k_1 = 0{,}04\dfrac{A_1}{A_2} + 0{,}2\left(\dfrac{y}{B} - 0{,}19\right) + 0{,}25$ Member 2 $k_2 = -0{,}04\dfrac{A_1}{A_2} - 0{,}2\left(\dfrac{y}{B} - 0{,}19\right) + 0{,}25$ Member 3 $k_3 = 0{,}5$

Symbols

i = structural index for different hull configurations
= 1 or 3, the side shell at the section under consideration
= 2 or 4, the longitudinal bulkheads at the section of consideration

A_T = half the total effective shear area at the section under consideration in cm^2, $A_T = \Sigma A_i$

A_i = the area of structural member i at the section under consideration in cm^2
In the event of part of the structural member being non-vertical A_i is to be calculated using the projected area in the vertical direction, *see* Fig. 4.2.2

y is the distance of structural member 2 from the centreline

B is given in 1.3.1

NOTES
1. For hull configurations not included above, k_i factors are to be specially considered.
2. Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead(s) to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas A_i.

t_i = the plate thickness of the structural member at the vertical level and section under consideration, in mm

k_i = factors determined from Table 4.2.2 for the hull configuration under consideration

f_{hts} and τ_o are defined in 1.3.1.

2.3.6 The design shear stress for each structural member, τ_{hg}, due to hull girder shear forces is given by

$$\tau_{hg} = \frac{|Q_R|\,A_z}{I\,\delta_i}$$

where
Q_R, A_Z, I and δ_i are given in 2.3.5.

2.3.7 Where a plate is tapered, the permissible combined shear stress is not to be exceeded at any point in way of the taper, *see* Fig. 4.2.1.

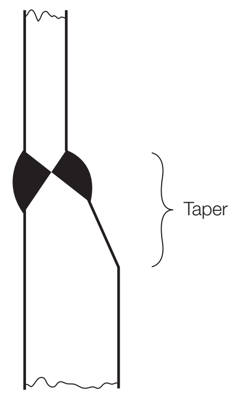


Fig. 4.2.1 Tapered plates

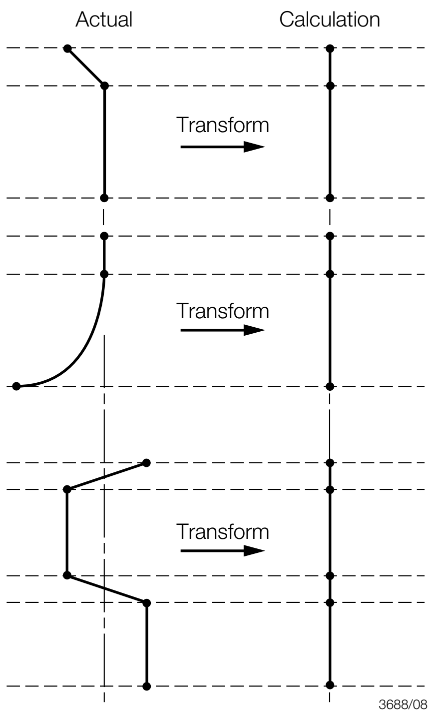


Fig. 4.2.2
Calculation of A_i for non vertical parts of structural members
(referenced from Table 4.2.2)

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering ships with large deck openings, unusual form or proportions, or special operating modes which induce significant torsional stresses. Calculations may in general be required to be carried out using direct calculation procedures. Such calculations are to be submitted in accordance with 1.5.

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within $0{,}4L_R$ amidships and where:

$l_1 > b_1 + 3h_1$

where

l_1 = length of first tier, in metres
b_1 = breadth of first tier, in metres
h_1 = 'tween deck height of first tier, in metres.

2.5.2 For superstructures with one or two tiers extending outboard to the ship's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\,((\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma)\,f(\lambda, \mathrm{N}) \times 10^{-7}$$

where

$f(1, \mathrm{N} = 1) = 1$
$f(\lambda, \mathrm{N} = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7l_1$
= 2 if $l_2 \geq 0{,}7l_1$

$\lambda = \dfrac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for N = 1
$= (2l_1 + l_2)/3$ for N = 2

L_R is defined in 1.2.1, in metres
l_1, b_1, h_1 are defined in 2.5.1, in metres
l_2 = length of second tier, in metres.

2.5.3 The design stress due to hull girder bending, σ_{hg}, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_{hg} = \frac{\eta_s M_R}{1000 Z_s} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at amidships due to sagging as determined in Pt 5, Ch 4,5, in kNm
Z_s = section modulus at the structural element being considered, in cm^3. The section modulus is to include the superstructure tiers, assuming the tiers to be η_s effective.
η_s = as defined in 2.5.2.

2.5.4 The stresses in the superstructure decks and sides are to be checked against buckling in accordance with 2.6. These stresses should also comply with the stress criteria in 2.2.3.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0\, h}{I_{100}}\right)^{-1}$$

where

η_s is defined in 2.5.2

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

2.6 Buckling strength

2.6.1 The buckling requirements in Ch 2,4 are to be applied to plate panels and longitudinals subject to hull girder compression and shear stresses. The design stresses are to be based on the design values of still water and wave bending moments and shear forces and are given in 2.2.4 and 2.3.6. The design factors of safety are given in Chapter 5.

2.6.2 When a Level 2 extreme strength assessment is applied, the Owner may specify that the buckling assessment of plate panels subject to compressive stresses is not required. In this case the buckling requirements of Ch 2,4.3 may be relaxed. The requirements of Ch 2,4.6 for shear buckling and the remainder of Ch 2,4 must always be complied with.

■ *Section 3* Extreme Strength Assessment, ESA

3.1 General

3.1.1 The extreme hull girder strength of the ship is to be adequate to withstand wave loads that have a very low probability of occurring during the ship's service life at sea.

3.1.2 The Owner may specify that an extreme strength assessment is not required. In this case, the extreme strength **ESA1** or **ESA2** notation and all other notations which require the extreme strength notation will not be assigned.

3.1.3 The extreme strength capability of the ship to survive severe sea conditions can be assessed using fairly simple or more advanced analysis procedures.The level of complexity and thoroughness of the analysis procedure is reflected in the extreme strength assessment notation level assigned.

3.1.4 Two assessment levels are available for the extreme hull girder strength assessment notation. These are summarised below:

ESA1 – Level 1

- Extreme hull girder strength considered at a minimum of three longitudinal locations.
- Capability assessed using elastic analysis, limiting stress criteria and buckling factors of safety.

ESA2 – Level 2

- Extreme hull girder strength considered at all critical longitudinal locations.
- Capability assessed using elasto-plastic ultimate strength methods to determine extreme hull girder strength.

3.1.5 For the **ESA1** assessment, the extreme hull girder strength is to be verified using elastic theory, based on the actual section moduli and determination of the buckling strength to resist the global hull girder loads. The assessment criteria are given in 3.3 to 3.4. Alternatively the strength may be verified using ultimate strength methods.

3.1.6 For the **ESA2** assessment, the extreme hull girder strength is to be verified using ultimate strength methods based on non linear stress strain curves which include the stress strain relationship in the post buckling phase. The assessment criteria are given in 3.5.

3.2 Determination of critical sections

3.2.1 A critical section is defined as a transverse cross-section of the hull where the hull girder bending or shear section structural properties are lowest. Typically there will be critical sections in way of machinery spaces, large deck openings and at the ends of superstructure blocks.

3.2.2 The effective geometric properties of critical sections are to be calculated in accordance with 2.2.1 and 1.4. In defining the longitudinal position of each critical section, the shadow areas specified in 1.4.13 are to be considered together with the proximity of other openings, *see* 1.4.15.

3.2.3 For the **ESA1** assessment, critical sections are to be considered at approximately the longitudinal positions $L_R/4$, $L_R/2$ and $3L_R/4$. Other longitudinal positions may also need to be considered depending on the structural arrangement of the ship.

3.2.4 For the **ESA2** assessment, critical sections are to be considered at all positions along the length. Typically it is expected that the local critical transverse section between adjacent main watertight bulkheads will be evaluated.

3.3 Bending strength – Simplified assessment method ESA1

3.3.1 If the simplified analysis method is adopted for extreme strength assessment, the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

$\sigma_{BEX} < \sigma_p$

$\sigma_{DEX} < \sigma_p$

where

σ_p is the maximum permissible hull vertical bending stress, in N/mm^2

$= f\sigma_{EX}\ \sigma_o$

$f_{\sigma EX}$ = 0,9, limiting hull bending stress coefficient

σ_{DEX} is the extreme hull girder bending stress at strength deck

$$= \frac{M_{REX}}{1000 Z_D}$$

σ_{BEX} is the extreme hull girder bending stress at keel

$$= \frac{M_{REX}}{1000 Z_B}$$

M_{REX} = extreme vertical wave and still water bending moment, in kNm, given in Pt 5, Ch 4,4.7

Z_D = actual section modulus at deck, in m^3

Z_B = actual section modulus at keel, in m^3

f_{hts} and σ_o are defined in 1.3.1.

3.3.2 The design extreme stress due to the extreme hull vertical bending moment, σ_{ex}, for each structural member is given by

$$\sigma_{ex} = \frac{M_{REX}}{1000 Z_i}$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_{REX} is defined in 3.3.1.

3.3.3 It is not necessary to satisfy the plate panel buckling requirements for compressive stresses provided that shear buckling of plate panels and stiffened panels and all buckling modes of failure for longitudinal girders and stiffeners are satisfied. The design factors of safety are given in Chapter 5.

3.3.4 Consequently, the following sections on buckling control are to be complied with, based on compressive stresses derived in accordance with 3.3.2:

(1) Secondary stiffening in direction of compression, Ch 2,4.7.

(2) Secondary stiffening perpendicular to direction of compression, Ch 2,4.8.

(3) Buckling of primary members, Ch 2,4.9.

3.4 Shear strength – Simplified assessment method ESA1

3.4.1 If the simplified analysis method is adopted for extreme strength assessment, the shear strength of the ship at each critical section is to satisfy the following criterion:

$$\frac{|Q_{REX}|\,A_z}{I\delta_0} \leq \tau_p$$

where

δ_0 is to be taken as the minimum value of δ_i

τ_p = maximum permissible mean shear stress, in N/mm^2

$= f_{\tau EX}\ \tau_o$

$f_{\tau EX}$ = 0,9, limiting hull shear stress coefficient

Q_{REX} = extreme vertical wave and still water shear force, in kN, at the appropriate longitudinal position determined from Pt 5, Ch 4,4.7

A_z, I and δ_i, are given in 2.3.5

f_{hts} and τ_o are defined in 1.3.1.

3.4.2 The design extreme shear stress due to extreme hull vertical shear forces for each structural member, τ_{ex}, due to hull girder is given by

$$\tau_{ex} = \frac{|Q_{REX}|\,A_z}{I\delta_i} \leq \tau_p$$

where

Q_{REX} is given in 3.4.1

A_z, I and δ_i are given in 3.4.1.

3.4.3 The following sections on buckling control are to be complied with based on shear stresses derived in accordance with 3.4.2:

(1) Plating subject to pure in-plane shear, Ch 2,4.3.

(2) Shear buckling of stiffened panels, Ch 2,4.6.

The design factors of safety are given in Chapter 5.

3.5 Bending and shear strength – Ultimate strength analysis method ESA2

3.5.1 The extreme strength capability of the hull girder may be assessed using a direct calculation ultimate strength analysis method. In this case the longitudinal strength of the ship at each critical section is to satisfy the following criteria for hogging and sagging conditions:

$M_{REX} < f_{UEX}\, M_{UEX}$

$Q_{REX} < f_{UEX}\, Q_{UEX}$

where

M_{REX} = extreme vertical wave and still water bending moment, in kNm, given in Pt 5, Ch 4,4.7

M_{UEX} = ultimate bending strength of the critical section, in kNm

Q_{REX} = extreme vertical wave and still water shear force, in kN, at the appropriate longitudinal position determined from Pt 5, Ch 4,4.7

Q_{UEX} = ultimate shear strength of the critical section, in kN

f_{UEX} = 0,9, limiting ultimate strength coefficient for extreme hull girder strength assessment.

3.5.2 The ultimate strength of each critical section is to be derived by direct calculation using elasto-plastic analysis methods.

3.5.3 If the methods used to derive the ultimate strength do not include allowance for shear loading, then the shear strength requirements of 3.4 are to be applied.

■ *Section 4* Residual Strength Assessment, RSA

4.1 Application

4.1.1 This Section gives the requirements and procedures to be adopted for the application of the residual strength assessment procedure.

4.1.2 The following definition gives the basic default mission statement for the residual strength capability. The ship is required to have a 95 per cent probability of surviving for 96 hours, after sustaining structural damage as a consequence of military action, collision or grounding, in wave conditions that have a probability of occurring for 80 per cent of the time.

4.1.3 Three assessment levels are available for the residual strength assessment notation as detailed in 1.2.

4.1.4 For the **RSA1** residual strength assessments the residual strength after damage is to be verified using the simplified assessment method given in 4.4 and 4.5. This uses elastic theory, based on the remaining section moduli and area after damage, and determination of the buckling strength to resist the global hull girder loads.

4.1.5 For the **RSA2** residual strength assessments, the residual strength after damage is to be verified using the ultimate strength analysis method which determines the ultimate strength of the hull after damage using direct calculation methods. The assessment criteria are given in 4.6.

4.1.6 For the **RSA3** residual strength assessments, the residual strength after damage is to be verified using a recognised finite element code suitable for this type of analysis. The failure will be determined by the criteria implicit in the finite element code chosen. Several assessment codes are available and the calculation should be performed by a competent and experienced body with relevant experience.

4.1.7 All critical sections to be assessed are to be considered for all damage scenarios, irrespective of whether the critical section is damaged or not.

4.1.8 For damage scenarios that involve flooding of the ship, the effects of the flood water on the still water shear forces and bending moments are to be considered in the residual strength assessment at all critical locations whether they are damaged or not. In the latter case the capability of the undamaged critical section will be based on the structural capability of the intact section.

4.2 Extent of damage and analysis

4.2.1 The extent of damage to be considered is defined below. Unless otherwise stipulated by the Owner it will not be necessary to consider the consequences of combining damage extents from different weapon threats or damage scenarios.

4.2.2 The extent of damage due to military threats is defined as the minimum of the shock or blast damage that is likely to result from a specified weapon threat. The weapon threat may be specified by any of the following:

- the residual strength notation threat level, *see* Pt 4, Ch 2,7;
- the Owner;
- as a direct consequence of requirements of other notations.

4.2.3 Collision damage to the side shell. The standard damage extent is to be taken as:

Level A

- 5 m longitudinally between bulkheads
- from the waterline up to the main deck
- inboard for B/5 m.

Level B and C

- 5 m longitudinally anywhere including bulkheads
- from the bilge keel up to the main deck
- inboard for B/5 m.

4.2.4 Grounding or raking damage to the bottom structure. The standard grounding damage extent is to be taken as:

Level A

- length of 5 m anywhere forward of midships
- upwards for 1 m or to the underside of the inner bottom, whichever is less
- breadth of 2,5 m.

Level B and C

- length of 0,1*L* anywhere forward of midships
- upwards for 1 m or to the underside of the inner bottom, whichever is less
- breadth of 5 m.

4.2.5 For the Levels A and B residual strength assessment, the residual strength is to be considered at a minimum of three critical sections for each anticipated damage extent. The critical sections are to be taken in the midship region and near each quarter length location. For the Level C residual strength assessment, the residual strength is to be considered at all critical sections along the length for each anticipated damage extent.

4.2.6 The damage requirements used for the residual strength assessment should be clearly identified in the Loading Manual or Stability Information Book.

4.3 Determination of critical sections

4.3.1 The effective geometric properties of critical transverse sections in way of the damaged area are to be calculated in accordance with 2.1 and 1.4. In defining the longitudinal position of each critical section, the shadow areas associated with the damage and other openings specified in 1.5.3 are to be considered together with the proximity of other openings, *see* 1.5.5. The effectiveness of the superstructure may also need to be re-evaluated.

4.3.2 Due attention is to made to the effectiveness of structure which may have been plastically deformed, as a consequence of the damage, on the ultimate strength after damage.

4.3.3 For Level 1 and 2 residual strength assessments, damaged areas are to be considered at approximately the longitudinal positions $L_R/4$, $L_R/2$ and $3L_R/4$. The geometric properties of critical transverse sections in way of these damaged areas are to be considered. Other longitudinal positions may also need to be considered depending on the internal arrangement or structural arrangement of the ship or the Owner's required residual strength specification.

4.3.4 For Level 3 residual strength assessment, damaged areas are to be considered at all positions along the length. Typically, it is expected that the local critical transverse section between adjacent main watertight bulkheads will be evaluated.

4.4 Bending strength – Simplified assessment method RSA1

4.4.1 If the simplified analysis method is adopted for residual strength assessment, the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

$$\sigma_{BRS} < \sigma_p$$
$$\sigma_{DRS} < \sigma_p$$

where

σ_p is the maximum permissible hull vertical bending stress, in N/mm^2
$= f_{\sigma RS}\, \sigma_o$

$f_{\sigma RS}$ = 0,9, limiting hull bending stress coefficient

σ_{DRS} is the hull girder bending stress at strength deck

$$= \frac{M_{RRS}}{1000 Z_{DRS}}$$

σ_{BRS} is the hull girder bending stress at keel

$$= \frac{M_{RRS}}{1000 Z_{BRS}}$$

M_{RRS} = residual strength design vertical bending moment, in kNm, given in Pt 5, Ch 4,5.7

Z_{DRS} = actual section modulus at deck of damaged section, in m^3, *see also* 4.1.13

Z_{BRS} = actual section modulus at keel of damaged section, in m^3, *see also* 4.1.13

f_{hts} and σ_o are defined in 1.3.1.

4.4.2 The design residual strength stress due to the Residual strength design vertical bending moment, σ_{rs}, for each structural member is given by:

$$\sigma_{rs} = \frac{M_{RRS}}{1000 Z_i}$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_{RRS} is defined in 4.4.1.

4.4.3 It is not necessary to satisfy the plate panel buckling requirements for compressive stresses provided that shear buckling of plate panels and all buckling modes of failure for longitudinal girders and stiffeners are satisfied. The design factors of safety are given in Chapter 5.

4.4.4 Consequently, the following sections on buckling control are to be complied with, based on compressive stresses derived in accordance with 4.4.2:

(1) Secondary stiffening in direction of compression, Ch 2,4.7.
(2) Secondary stiffening perpendicular to direction of compression, Ch 2,4.8.
(3) Buckling of primary members, Ch 2,4.9.

4.5 Shear strength – Simplified assessment method RSA1

4.5.1 If the simplified analysis method is adopted for residual strength assessment, the shear strength of the ship after damage at each damaged critical section is to satisfy the following criterion:

$$\frac{|Q_{RRS}|\, A_z}{I \delta_0} \leq \tau_p$$

where

δ_0 is to be taken as the minimum value of δ_i,

and

τ_p = maximum permissible mean shear stress, in N/mm^2
$= f_{\tau EX}\, \tau_o$

$f_{\tau EX}$ = 0,9, limiting hull shear stress coefficient

Q_{RRS} = residual strength design shear force, in kN, at the appropriate longitudinal position determined from Pt 5, Ch 4,5.7

A_z, I and δ_i, are to be calculated in accordance with the method in 2.3 for the damaged section, *see also* 4.1.13.

f_{hts} and τ_o are defined in 1.3.1.

4.5.2 The design extreme shear stress due to residual strength design shear force for each structural member, τ_{rs}, is given by

$$\tau_{rs} = \frac{|Q_{RRS}|\, A_z}{I \delta_0}$$

where

Q_{RRS} is given in 4.5.1

A_z, I and δ_i are given in 2.3.5.

4.5.3 The following sections on buckling control are to be complied with based on shear stresses derived in accordance with 4.5.2:
(1) Plating subject to pure in-plane shear, Ch 2,4.3.
(2) Shear buckling of stiffened panels, Ch 2,4.6.
The design factors of safety are given in Chapter 5.

4.6 Bending and shear strength – Ultimate strength analysis method RSA2

4.6.1 The residual strength capability of the damaged hull girder may be assessed using a direct calculation ultimate strength analysis method. In this case the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

$$M_{RRS} < f_{URS} M_{URS}$$
$$Q_{RRS} < f_{URS} Q_{URS}$$

where

M_{RRS} = residual strength design vertical bending moment, in kNm, given in Pt 5, Ch 4,5.7
M_{URS} = ultimate bending strength of the damaged critical section, in kNm, *see also* 4.1.13
Q_{RRS} = residual strength design shear force, in kN, at the appropriate longitudinal position determined from Pt 5, Ch 4,5.7
Q_{URS} = ultimate shear strength of the damaged critical section, in kN
f_{URS} = 0,9, limiting ultimate strength coefficient for residual strength assessment.

4.6.2 The ultimate strength of each critical section is to be derived by direct calculation using elasto-plastic analysis methods.

4.6.3 If the methods used to derive the ultimate strength do not include allowance for shear loading, then the shear strength requirements of 4.5 are to be applied.

Section

■ *Section 1* Structural design factors

1.1 Application

1.1.1 The requirements of this Chapter are applicable to ships of steel construction.

1.2 General

1.2.1 This Chapter gives the allowable design criteria to be used to assess the structure.

1.2.2 These design criteria are to be used in the design formulae in Ch 3,2 as the design criteria for the scantling determination of NS2 and NS3 ships.

1.2.3 These criteria are also to be used when direct calculation methods are proposed as a supplement to the scantling determination procedures for all ships including NS1 ships.

1.2.4 Where higher tensile steel is used in the ship structure special consideration is to be given to the fatigue performance in accordance with Ch 6,2.5.

1.3 Higher tensile steel

1.3.1 Where higher tensile steels are used, the yield stress is to be adjusted by a factor f_{hts}, where f_{hts} is to be taken from Table 5.1.1.

Table 5.1.1 High tensile steel stress correction factor f_{hts}

Minimum yield stress σ_o N/mm^2	f_{hts} factor	
	Global loads	Local loads
235	1,000	1,00
265	0,964	1,00
315	0,956	1,00
355	0,919	1,00
>390	$0{,}886\left(\dfrac{390}{\sigma_o}\right)$	$0{,}91\left(\dfrac{390}{\sigma_o}\right)$

NOTES
1. Intermediate values may be obtained by linear interpolation.
2. The higher tensile steel stress correction factor f_{hts} is applicable for NS1 ships as well as NS2 and NS3 ships.

1.3.2 The f_{hts} factor is to be separately calculated for stresses that are a direct consequence of global loads and for stresses that are a direct consequence of local loads, as indicated in Table 5.1.1.

■ *Section 2* Scantling determination for NS1 ships

2.1 Design criteria

2.1.1 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_o}$$

or 0,66 whichever is greater

where

σ_o = specified minimum yield strength of material in N/mm^2

2.1.2 The global scantling requirements of higher tensile steel plating, stiffeners and primary members are based on a k_L factor defined as follows, *see* 2.1.3:

$$k_L = \frac{235}{f_{hts}\,\sigma_o}$$

where

f_{hts} is the higher tensile steel correction factor for global loads, *see* 1.3.

2.1.3 Where different grades of steel are used for the plating and attached stiffeners, then the higher tensile steel factor, k_L is to be based on the lower material yield strength.

■ *Section 3*
Scantling determination for NS2 and NS3 ships

3.1 Design criteria

3.1.1 The allowable stress coefficients for plating and stiffening required by Ch 3,2 for use in plating and stiffening design equations in Ch 2,2.7 and 2.8 are to be determined as follows:

$f_\sigma = f_1 f_{hts}$
$f_\tau = f_1 f_{hts}$
$f_\delta = f_1$

where
f_1 is taken from Table 5.3.2 as specified by Table 5.3.1
f_{hts} is the correction factor for higher tensile steel given in 1.3.

3.1.2 The buckling factors of safety for plating and stiffeners are given in Table 5.3.2 and are to be used in conjunction with the buckling requirements specified in Ch 2,4.

3.1.3 The assessment of scantling requirements to satisfy the impact or slamming pressure loads for plating and stiffening are given in Ch 3,14 and Ch 3,15.

Table 5.3.1 Specification of design criteria value f_1

Failure mode	Stress factor	Column for f_1 in Table 5.3.2
Plating requirements		
Membrane stresses	f_σ	Use σ_x or σ_y column (1)
Local plate bending	f_σ	Use σ_b column
Shear stresses	f_τ	Use τ_{xy} column
Buckling, hull girder stresses	λ_σ	Use λ_σ column
Shear buckling, hull girder stresses	λ_τ	Use λ_τ column
Stiffener requirements		
Hull girder plus local bending	f_σ	Use σ_{vm} column
Local stiffener bending	f_σ	Use σ_x or σ_y column (1)
Web area	f_τ	Use τ_{xy} column
Inertia	f_δ	Use f_δ column
Buckling modes	λ_σ	Use λ_σ column

NOTE
Use the σ_x or σ_y column as appropriate to the structure under consideration.

Table 5.3.2 Allowable stress factors f_1 (*see continuation*)

Structural item	Limiting stress and other criteria						
Longitudinally effective structure	Combined stress	Longitudinal stress or stiffener bending stresses	Shear stress in Plating and Stiffener webs	Local plate bending	Deflection ratio for primary members and secondary stiffeners (3)	Buckling factor (5) Compressive stresses	Buckling factor (7) Shear stresses
Normal stress descriptor	σ_{vm}	σ_x	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ
Longitudinal plating							
Bottom shell plating	0,90	0,75	—	f_2	0,00125 (1)	1,0	—
Inner bottom plating	0,90	0,75 f_{WT}	—	$f_2 f_{WT}$	0,00125 (1)	1,0	—
Upper deck, outboard the line of openings	0,90	0,75	—	f_2	0,00100 (1)	1,0	—
Side shell plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Longitudinal bulkhead plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Inner skin plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Intermediate decks	—	—	—	0,65	—	—	—
Longitudinal primary members							
Double bottom girders	0,90	0,75	0,80	—	0,00100 (2)	1,0	1,1
Longitudinal girders	—	0,75	0,65	—	0,00100 (2)	1,0	1,1
Longitudinal stringer plating and diaphragms	—	0,75	0,65	—	0,00100 (2)	1,0	1,1
Longitudinal secondary stiffeners	0,90	f_2	0,65	—	*see* above plating	1,1 (4)	—
Other longitudinal plating and secondary stiffeners							
Superstructures/deckhouses (partially longitudinally effective)	0,90	0,75	0,65	0,75	0,00167 (1)	1,0	—
Watertight bulkheads and internal boundaries							
plating	0,90	0,75	0,80	f_{WT}	—	1,0	1,1
primary members	—	0,90 f_{WT}	0,90 f_{WT}	—	0,00100 f_{WT} (2)	1,1	—
secondary stiffeners	—	0,90 f_{WT}	0,95 f_{WT}	—	0,00167 f_{WT} (1)	1,1 (4)	—
Deep tank bulkheads and internal boundaries							
plating	0,90	0,75	0,80	0,65 f_{DT}	—	1,0	1,1
primary members	—	0,75 f_{DT}	0,75 f_{DT}	—	0,00080 f_{DT}(1)	1,1	—
secondary stiffeners	—	0,65 f_{DT}	0,65 f_{DT}	—	0,00100 f_{DT}(1)	1,1 (4)	—

Symbols

f_2 is applicable to stiffeners and plating subjected to global hull girder bending stresses and local bending stresses and is to be taken as follows:

for NS2 ships

$f_2 = 0{,}9\left(1{,}83 - \dfrac{\sigma_{hg}}{\sigma_a}\right)$ but not greater than 0,95. Note for initial design assessment f_2 may be taken as 0,75.

for NS3 ships

$f_2 = 0{,}75$

where

σ_{hg} is the stress due to hull girder bending in the appropriate structural item, *see* Ch 4,2

σ_a is the lower of:

(1) allowable hull girder stress, σ_p, given in Ch 4, 2.2.3

(2) $\dfrac{\sigma_{cr}}{\lambda_\sigma}$

λ_σ is the buckling factor for this item

σ_{cr} is the critical buckling stress, *see* Ch 2,4

Additional design factors for deep tank and watertight bulkheads and boundaries

f_{DT} = 0,90

f_{WT} = 1,40 Note watertight plating is assessed using plastic design methods

Table 5.3.2 Allowable stress factors f_1 (*conclusion*)

Structural item	Limiting stress and other criteria						
Transverse and local structure	Combined stress	Transverse stress or stiffener bending stress	Shear stress in Plating and Stiffener webs	Local plate bending	Deflection ratio for primary members and secondary stiffeners (3)	Buckling factor (5) Compressive stresses	Buckling factor (7) Shear stresses
Normal stress descriptor	σ_{vm}	σ_y	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ
Transverse plating							
Watertight bulkheads and internal boundaries	1,00	1,00	0,80	1,00 f_{WT}	0,00167f_{WT} (1)	1,0	1,1
Deep tank bulkheads and boundaries	0,75	0,65	0,65	0,65 f_{DT}	0,00100f_{DT} (1)	1,2	1,2
Cross deck structure at ends of major openings	0,75	0,65	0,65	0,50	0,00100 (1)	1,1	1,1
Superstructures/deckhouses (local loads only)	—	0,75	—	0,75	0,00167 (1)	—	—
Transverse primary members							
Double bottom floors	0,75	0,65	0,65	—	0,00100 (2)	1,1	1,2
Web frames	—	0,65	0,65	—	0,00100 (2)	1,1	—
Side frames	—	0,65	0,65	—	0,00100 (2)	1,1	—
Transverse beams	—	0,65	0,65	—	0,00100 (2)	1,1	—
Watertight bulkheads and internal boundaries	—	0,90 f_{WT}	0,90 f_{WT}	—	0,00100 f_{WT} (2)	1,1	—
Deep tank bulkheads and internal boundaries	—	0,75 f_{DT}	0,75 f_{DT}	—	0,00080 f_{DT} (2)	1,1	—
Transverse secondary stiffeners							
Watertight bulkheads and internal boundaries	—	0,95 f_{WT}	0,95 f_{WT}	—	*see* above plating	1,1 (4)	—
Deep tank bulkheads and internal boundaries	—	0,65 f_{DT}	0,65 f_{DT}	—		1,1 (4)	—
Other secondary stiffeners	—	0,65	0,65	—		1,1 (4)	—
Structure for aircraft and vehicle operation (8) (Additional requirements in accordance with Pt 4, Ch 3,2)	Combined stress	Primary member and stiffener bending stress	Shear stress in primary member and Stiffener webs	Local plate bending	Deflection ratio for primary members and secondary stiffeners (3)	Buckling factor of safety (6)	Buckling factor of safety (7)
Normal stress descriptor	σ_{vm}	σ_x or σ_y	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ
Vehicles and aircraft parking areas — secondary stiffeners	—	0,75 (8)	0,75	—	0,00100 (1)	—	—
Vehicles and aircraft parking areas — primary members	—	0,60 (8)	0,60	—	0,00080 (2)	—	—
Aircraft normal landing areas — secondary stiffeners	—	0,75 (8)	0,75	—	0,00100 (1)	—	—
Aircraft normal landing areas — primary members	0,70	0,65 (8)	0,65	—	0,00080 (2)	—	—
Aircraft emergency landing areas — secondary stiffeners	—	1,00 (8)	1,00	—	0,00160 (1)	—	—
Aircraft emergency landing areas — primary members	—	1,00 (8)	1,00	—	0,00100 (2)	—	—

NOTES
1. Deflection ratio for secondary stiffeners, expressed as a ratio of the stiffener's span, i.e. $\delta \leq f_\delta$ span where δ is the deflection.
2. Deflection ratio for primary structure, expressed as a ratio of the primary member's span, i.e. $\delta \leq f_\delta$ span.
3. The deflection ratios are applicable to the primary members and secondary stiffeners attached to the specified plating areas. The ratios are not applicable to the plating.
4. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* Ch 2,4.5.
5. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
6. Buckling factor of safety to be applied to the compressive stress due to local stresses, either vertical or transverse.
7. Buckling factor of safety to be applied to the shear stress.
8. For longitudinally effective primary structure and longitudinal stiffeners, the stress factor is to be reduced by:
   0% at 0,0L_R,
   30% at 0,3L_R,
   30% at 0,7L_R,
   0% at 1,0L_R
   with intermediate values determined by interpolation.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull ships of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel ships using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 Specific requirements containing detailed information on testing, inspection and construction details can be found in the relevant chapters of the *Naval Ship Survey Procedures Manual*.

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or Naval Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct ships to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by subcontractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of ships and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.
(b) LR's Quality Assurance Scheme for the Hull Construction of Ships.
(c) LR's Quality Assurance Scheme for the Construction of Special Service Craft.
(d) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:
    (i) Receipt storage and issue of materials, equipment, etc.
    (ii) Fabrication environment.
    (iii) Weld procedures and welder performance.
    (iv) Production fabrication.
    (v) Inspection of production processes.
    (vi) Installation of machinery and essential systems.
    (vii) Fitting-out.
    (viii) Tests and trials.
    (ix) Drawings and document control.
    (x) Records.

1.6.3 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously which of the activities specified in 1.6.2(d) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.4 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The ship is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Survey.

1.10.2 Production faults are to be discussed with the Owner and attending Surveyor, and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 New building inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyors responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection. Consideration also needs to be given to provide arrangements that facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable linings.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.3.

1.11.6 Building and repair tolerances are given in the Naval Ship Survey Guidance Manual.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.3.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The Rules relate in general to the construction of steel ships, although consideration will be given to the use of other materials.

2.1.2 Materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of Part 2.

2.1.3 Materials for which provision is not made therein or covered by this section may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 In order to distinguish between the material grade requirements for different hull members, material classes are assigned as given in Table 6.2.1 and Fig. 6.2.1. Steel grades are not to be lower than those corresponding to the material classes as given in Table 6.2.2.

2.2.3 Ships operating in certain environmental conditions, and those where operational requirements may lead to a risk of impact damage, or ships with military notations, may require higher toughness grades.

2.2.4 Where a ship has the notations **FDA**, **ESA** or **RSA**, the toughness requirements for steel will be specially considered on the basis of fatigue crack limitation and subsequent propagation through the structure.

2.2.5 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with Pt 2, Ch 3,8. The plan should indicate the material grade followed by the letter Z (e.g. DZ, DHZ).

2.3 Refrigerated spaces

2.3.1 Where the minimum design temperature of the steel falls below 0°C in refrigerated spaces, the grade of steel for the following items is to comply, in general, with the requirements of Table 6.2.3:

- Deck plating.
- Webs of deck girders.
- Longitudinal bulkhead strakes attached to deck.

2.3.2 Unless a temperature gradient calculation is carried out to assess the design temperature in the items defined in 2.3.1, the temperature to which the steel deck may be subjected is to be assessed as shown in Table 6.2.4.

2.4 Ships operating in cold weather conditions

2.4.1 Unless otherwise specified, all ships designed for sea area SA1 and other ships intended to operate for extended periods in cold weather conditions, the minimum toughness requirements for the material of the hull structure are specified in Fig. 6.2.2 and Table 6.2.5. The requirements are based on a design air temperature of -30°C. Where an alternative design air temperature is required, the materials selected are to be in accordance with Pt 3, Ch 2,3 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships). In the absence of specific information, the air temperature should be taken as:

- for Ice class 1C strengthened ships not higher than –30°C,
- for first year ice strengthened ships not higher than –40°
- for multi year ice strengthened ice breaking ships not higher than –50°.

In all cases the water temperature should not be taken higher than –10°C.

2.4.2 Cold weather is defined as that which will cause the temperature to fall below 0ºC.

Table 6.2.1 Material classes and grades

Structural member category	Within $0,3L_R$ to $0,7L_R$	Outside $0,3L_R$ to $0,7L_R$
SECONDARY: • Lower strake in longitudinal bulkhead • Deck plating exposed to weather, in general • Side plating	I	0
PRIMARY: • Bottom plating, including keel plate • Strength deck plating, *see* Note 1 • Continuous longitudinal members above strength deck • Upper strake in longitudinal bulkhead	II	0
SPECIAL: • Sheerstrake or rounded gunwale, *see* Note 3 • Stringer plate at strength deck, *see* Note 3 • Deck strake at longitudinal bulkhead, *see* Note 4 • Bilge strake, *see* Notes 5 and 6	III III	II, in general I, outside $0,2L_R$ to $0,8L_R$

NOTES
1. Plating at corners of large hatch openings is to be of Class III within $0,5L_R$ amidships and Class I elsewhere.
2. Corner insets in way of any complex openings such as for lifts and side doors which may impinge on the deck plating or stringer plate, are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm.
3. In ships with length exceeding 250 m, sheerstrake or rounded gunwale and stringer plate at strength deck are not to be less than Grade E/EH within $0,3L_R$ to $0,7L_R$.
4. In ships with breadth exceeding 70 m, at least three deck strakes in board of the sheerstrake or rounded gunwale, including the stringer plate at the strength deck,are to be of Class III within $0,3L_R$ to $0,7L_R$.
5. In ships with a double bottom over the full breadth and with length less than 150 m, bilge strake may be of Class II within $0,3L_R$ to $0,7L_R$.
6 In ships with length exceeding 250 m, bilge strake is not to be less than Grade D/DH over its entire length.
7. For strength members not mentioned, Grade 0 may generally be used.
8. Within $0,3L_R$ to $0,7L_R$, single strakes required to be of Class III or of Grade E/EH are to have breadths not less than 800 + $5L_R$ mm, but need not be greater than 1800 mm.
9. The material class used for reinforcement and the quality of material (i.e. whether mild or higher tensile steel) used for welded attachments, such as waterway bars and bilge keels, is to be similar to that of the hull envelope plating in way. Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.
10. The material class for deck plating, sheerstrake and upper strake of longitudinal bulkhead within $0,3L_R$ to $0,7L_R$ is also to be applied at structural breaks in the superstructure regardless of position.
11. Engine seat top plates outside $0,2L_R$ to $0,8L_R$ may be Grade A/AH. Steel grade requirement for top plates within $0,2L_R$ to $0,8L_R$ will be specially considered.
12. Steel grade is to correspond to the as-fitted thickness.
13. Plating materials for sternframes, rudders, rudder horns and shaft brackets are, in general, not to be of lower Grades than corresponding to Class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semi-spade rudders or at upper part of spade rudders) Class III is to be applied.
14. Steel grade in way of bilge keels is to comply with the requirements of Ch 6,5.9.
15. RAS seating and support structure are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm. For ships operating in cold weather RAS seating and support structure are to be of grade E/EH.

Table 6.2.2 Steel grades for normal operation

Thickness, in mm	Class							
	O		I		II		III	
≤10	A	AH	A	AH	A	AH	A	AH
10–15	A	AH	A	AH	A	AH	A	AH
15–20	A	AH	A	AH	A	AH	B	AH
20–25	A	AH	A	AH	B	AH	D	DH
25–30	A	AH	A	AH	D	DH	E	EH
30–35	A	AH	B	AH	D	DH	E	EH
35–40	A	AH	B	AH	D	DH	E	EH
40–45	B	AH	D	DH	E	EH	E	EH
45–50	B	AH	D	DH	E	EH	E	EH

Table 6.2.3 Grades of steel for refrigerated spaces

Minimum design temperature, in °C	Thickness, in mm	Grades of steel
0 to – 10	$t \leq$ 12,5 12,5 < $t \leq$ 25,5 $t >$ 25,5	B/AH D/DH E/EH
–10 to – 25	$t \leq$ 12,5 $t >$ 12,5	D/DH E/EH
–25 to – 40	$t \leq$ 12,5 $t >$ 12,5	E/EH FH/LT–FH (*see also* Pt 2, Ch 3,6)

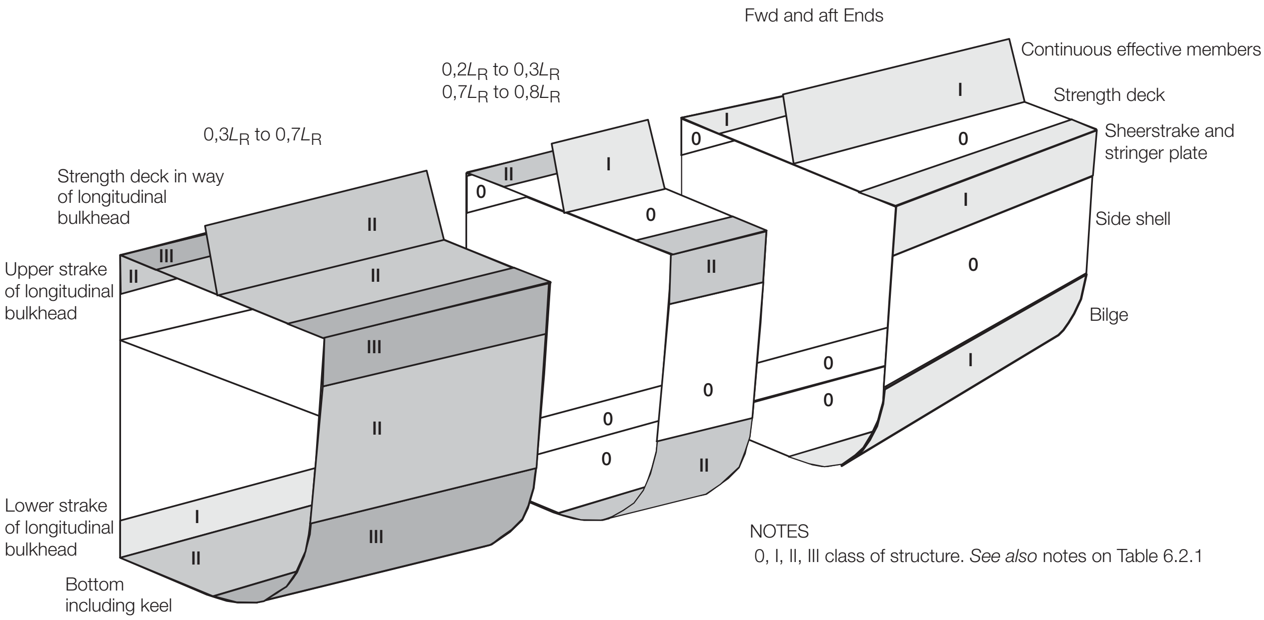


Fig. 6.2.1 Distribution of material for normal operation

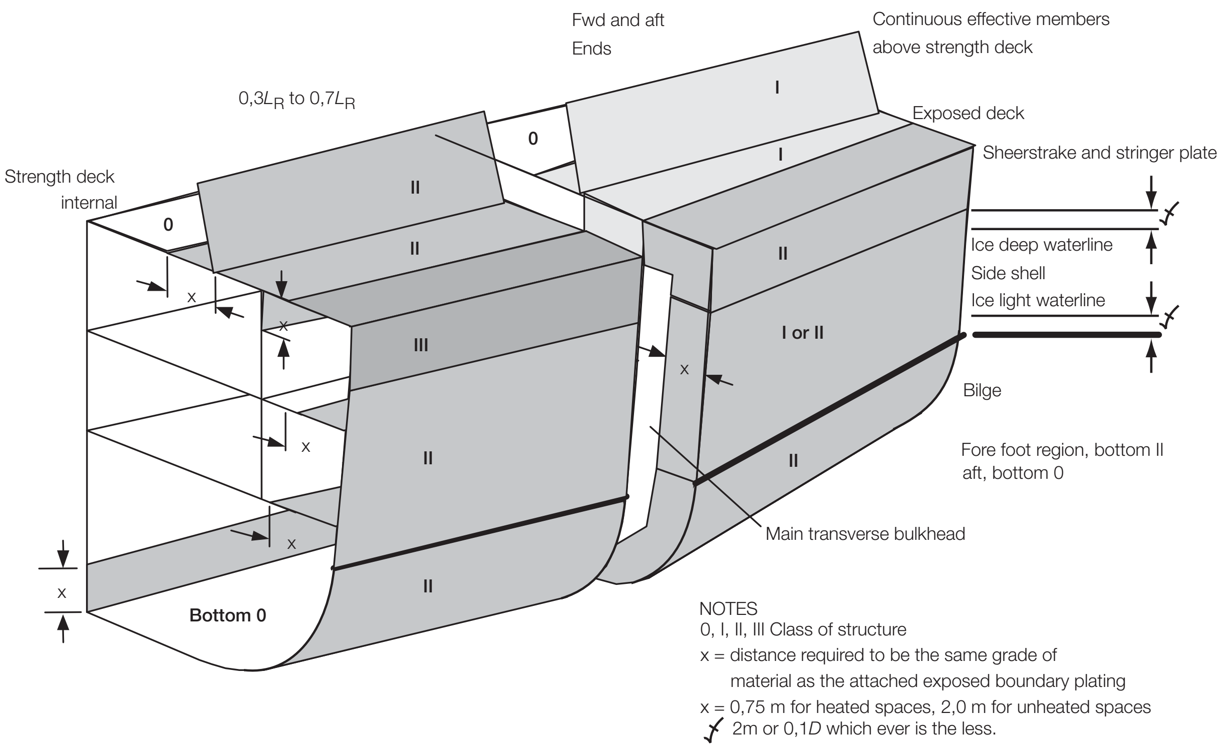


Fig. 6.2.2 Distribution of material for cold weather classes

Table 6.2.4 Assessment of deck temperature

Arrangement	Deck temperature
(1) Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
(2) Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side
(3) Deck covered with insulation on both sides	
(a) Temperature difference not greater than 11°C	Mean of the temperatures of the spaces above and below the deck
(b) Temperature difference greater than 11°C but not greater than 33°C	Mean of the temperatures of the spaces above and below the deck less 3°C
(c) Temperature difference greater than 33°C	Deck temperature will be specially assessed
NOTE Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5°C.	

2.4.3 In addition to the requirements of Fig. 6.2.2 all bulwarks, spurn waters, unlagged gas turbine intake structures, side screens, tie down points etc.are to be constructed of steel of equivalent toughness to that of the material to which they are attached.

2.4.4 Plating at the corners of deck openings, superstructure ends and other structural discontinuity is to be specially considered. The requirements of Class III are to be applied in positions where high local stresses may occur but the material is not to be less than Grade E.

Table 6.2.5 Steel grades for cold weather operation

Thickness, in mm	Class							
	O		I		II		III	
≤10	B	AH	B	AH	D	DH	D	DH
10–15	B	AH	D	DH	D	DH	E	EH
15–20	B	AH	D	DH	D	DH	E	EH
20–25	B	AH	D	DH	E	EH	E	EH
25–30	B	AH	D	DH	E	EH	E	EH
30–35	B	AH	D	DH	E	EH	F	FH
35–40	B	AH	E	EH	E	EH	F	FH
40–45	B	AH	E	EH	F	FH	F	FH
45–50	B	AH	E	EH	F	FH	F	FH

2.4.5 In ships where L_R is >250 m, the shear stringer plate is not to be less than Grade E or EH from $0,3L_R$ to $0,7L_R$.

2.4.6 Steel grades for rudder horn and stem (including the adjacent strake of shell plating), are given in Table 6.2.7. The steel grades of internal members attached to these items are to be of the same grade (or equivalent) with due account taken of difference in thickness.

2.4.7 In general, longitudinal frames and outboard strakes of horizontal stringers, transverse frames and web plating are to be of the same steel grade as the plating to which they are connected, but the grade may be adjusted to take account of difference in thickness.

2.4.8 The structure of internal spaces not included in Table 6.2.1 are to be in accordance with Table 6.2.6.

Table 6.2.6 Cold weather requirements for internal structure (heated and unheated)

Structure in permanently heated spaces		
Location of structure	Structure	Requirement
Above Ice Light Waterline attached to exposed boundary stiffening	Lagged secondary and primary	As the exposed boundary
Above Ice Light Waterline attached to exposed boundary stiffening	Unlagged secondary and primary	Class O
Above Ice Light Waterline connected to an exposed boundary	Deck and bulkhead plating	As the exposed boundary
Below Ice Light Waterline adjacent to unheated fluid	Deck and bulkhead plating	Class O
Structure in all other spaces		
Location of space	Structure	Requirement
Above Ice Light Waterline	All	As exposed boundary
Below Ice Light Waterline with exposed boundary	All	As exposed boundary
Below Ice Light Waterline with no exposed boundary	All	Class O
NOTES Permanently heated spaces are those in which the internal air is maintained at a temperature above 15ºC. The exposed boundary is all that which is in contact with the external air or water including superstructure deckhouses and tanks.		

Table 6.2.7 Steel grades for rudder horn, shaft brackets and stem for ships intended to navigate in Arctic or Antarctic conditions

Item	Condition	Construction	Steel grade(2)(3) f < 25(1)	Steel grade(2)(3) $f \geq$ 25(1)
Rudder horn	Fully immersed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
		Fabricated	Grade EH	Grade EH
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 460	2¼ Ni steel or equivalent
		Fabricated	Grade FH	1½ Ni steel or equivalent
Shaft brackets	Fully immersed	Cast steel	Normal Rule requirement	Normal Rule requirement
		Fabricated	Class O	Class O
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 460
		Fabricated	Class II	Grade FH
Stem including adjacent strake of shell plating	Fully immersed	Fabricated	Class O	Class O
		Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
	Periodically immersed or exposed	Fabricated	Class II	Class II
		Cast steel	2¼ Ni steel	2¼ Ni steel
Rudder stock		Forged	*see* Pt 2, Ch 5,2.4.7	
		Cast steel	Carbon manganese steel grade 400	

NOTES
1. $f = \sqrt{P_o \Delta} \times 10^{-3}$
   where P_o is the maximum propulsion shaft power, in kW, for which the machinery is classed
   Δ is displacement, in tonnes, at Ice Load Waterline or Deepest Ice Operation Waterline when floating in water of relative density of 1,0.
2. For cast steel, *see* Pt 2, Ch 4,7.
3. For C–Mn LT60 and Ni plates, *see* Pt 2, Ch 3,6.

2.5 Mechanical properties for design

2.5.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400–490
Modulus of elasticity	200 x 103

2.5.2 Steels having a minimum yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

2.5.3 Factors for structural assessment are given in Chapter 5.

2.5.4 For the application of the requirements of 2.5.3 special consideration will be given to steel where $\sigma_o \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.6 Paints and coatings

2.6.1 All steelwork is to be suitably protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 The underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information. (*See also* Pt 1, Ch 3,4.3).

2.6.3 At the time of new construction, all salt water ballast spaces having boundaries formed by the hull envelope shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturers recommendations.

2.6.4 Details and recommendations regarding the coating of salt water ballast spaces are given in LR's *List of Paints, Resins, Reinforcements and Associated Materials*.

2.6.5 Integral tanks that contain only fuel, may be coated or, where applicable, be protected by a system of cathodic protection or both, *see* 2.7.

2.6.6 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating.

2.6.7 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.8 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in LR's *List of Paints, Resins, Reinforcements and Associated Materials*.

2.6.9 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.10 The paint or coating applied is to be compatible with any previously applied primer.

2.6.11 Paint containing aluminium should not, in general be used in positions where oil or fuel vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

2.6.12 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Cathodic protection

2.7.1 This section contains the requirements for the cathodic protection where fitted of the external hull and internal spaces.

2.7.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.7.3 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams, they are to be enclosed in a substantial steel tube of about 10 mm thickness.

2.7.4 Where anodes are fitted on the hull, a plan showing their location and method of attachment is to be submitted in accordance with Pt 6, Ch 1,2.2. They are to be fitted in such a way that they do not cause a stress concentration.

2.7.5 When a cathodic protection system is to be fitted in tanks for the carriage of liquid with flash point not exceeding 60°C, a plan showing details of the locations and attachment of anodes is to be submitted. The arrangements will be considered for safety against fire and explosion aspects only. Impressed current cathodic protection systems are not permitted in any tank.

2.7.6 Particular attention is to be given to the locations of anodes in relation to the structural arrangements and openings of the tank.

2.7.7 Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.7.8 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

2.7.9 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.7.10 When locating anodes, care is to be taken to ensure that they do not cause a stress concentration. Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.7.11 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil, but only at locations where the potential energy does not exceed 275 J. The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

2.7.12 The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1,0 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

2.7.13 Aluminium anodes are not to be located under tank hatches unless protected by adjacent structure.

2.7.14 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.8.2 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion.

2.8.3 Special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.9 Deck coverings

2.9.1 The steel deck is to be coated with a suitable material in order to prevent corrosive action.

2.9.2 Deck coverings within accommodation spaces, control stations, stairways and passageways are to be of a type which will not readily ignite or cause a smoke hazard.

2.9.3 Where plated decks are sheathed with wood, or an approved construction of suitable thickness, reductions in plate thickness may be allowed.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.10.3 In the absence of a specific requirement from the Owner, the following corrosion margins are to be applied to net scantlings calculated by these Rules regardless of the type of corrosion protection fitted:

+0,5 mm all plating below a line, 1,0 m, above the design waterline

+2,0 mm to the keel plate.

Consideration should also be given to the addition of a corrosion margin to the following areas:

- Plating and stiffening at the lower edge of bulkheads bounding wet spaces.
- All tanks containing corrosive fluids and areas where spillage of corrosive fluids could occur.
- All uncoated structures.

2.10.4 Ships with a corrosion margin will be eligible for an enhanced scantling notation, *see* Pt 3, Ch 6,6.

■ *Section 3* **Requirements for welded construction**

3.1 General

3.1.1 The requirements of this Section are applicable to grades of steel welded using electric arc welding processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.1.2 Symbols are defined as necessary in each Section.

3.1.3 Ships with enhanced shock notation are to additionally comply with the requirements of Pt 4, Ch 2.

3.1.4 The Rules represent the minimum requirement to satisfy classification. It is expected that the quality control procedures in place in the yard will be more stringent than the requirements of these Rules. The procedures should be based on an appropriate National Standard, the requirements of which will be similar to those in LR's *Materials and Qualifications Procedures for Ships*.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds. This requirement includes welded connections to steel castings.

3.2.2 The information to be submitted should include the following:

(a) Whether weld sizes given are throat thicknesses or leg lengths.
(b) Grades and thicknesses of materials to be welded.
(c) Location, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies, *see* 3.7.

3.3 Welding equipment

3.3.1 Welding plant and appliances are to be suitable for the purpose intended and properly maintained, taking due cognisance of relevant safety precautions.

3.3.2 Satisfactory storage facilities for consumables are to be provided close to working areas.

3.4 Welding consumables

3.4.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Pt 2, Ch 11.

3.4.2 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Flux-coated electrodes and submerged arc fluxes are to be stored under controlled conditions. Other welding consumables, such as bare wire and welding studs, are to be stored under dry conditions to prevent rusting. Prior to use, the welding consumables are to be baked as per the manufacturers' recommendations.

3.4.3 Steel welding consumables approved by LR, up to and including Grade Y40, are considered acceptable for marine construction in line with the following:

(a) Consumables are acceptable for welding steels up to three strength levels below that for which the approval applies (e.g. 3Y is acceptable for welding 36, 32 and 27S higher tensile ship steels and normal strength ship steel).
(b) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) (e.g. 3Y is acceptable for EH, DH and AH materials).

(c) For joints between steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required where attachments are made to main structural members of a higher grade or strength.

3.4.4 Where the carbon equivalent, calculated from the ladle analysis and using the formula given below, is in excess of 0,45 per cent, approved low hydrogen welding consumables and preheating are to be used. Where the carbon equivalent is above 0,41 per cent but is not more than 0,45 per cent approved low hydrogen welding consumables are to be used, but preheating will not generally be required except under conditions of high restraint or low ambient temperature. Where the carbon equivalent is not more than 0,41 per cent, welding consumables that have no hydrogen grading may be used and preheating will not generally be required except as above.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

The type of consumable and preheat proposed for low alloy steels will be subject to special consideration.

3.5 Welder qualifications

3.5.1 Welders and welding operators are to be proficient in the type of work on which they are engaged.

3.5.2 The responsibility for selection, training and testing of welding operators rests with the Builders. The Builders are to test welding operators to a suitable National or International Standard. Records of tests and qualifications are to be kept by the Builders and made available to the Surveyor so that he can be satisfied that the personnel employed during the construction of the ship can achieve the required standard of workmanship.

3.6 Welding procedures

3.6.1 Welding procedures, giving details of the welding process, type of consumables, joint preparation and welding position, are to be established for the welding of all joints.

3.6.2 Welding procedures are to be tested and qualified in accordance with a recognised National or International Standard. For this purpose, the sample joints are to be prepared under conditions similar to those that will occur during construction of the ship.

3.6.3 The proposed welding procedures are to be agreed with the Surveyor prior to construction.

3.6.4 Weld repairs, when required, are to be carried out in accordance with the approved procedures, *see also* 3.10.

3.7 Defined practices and welding sequence

3.7.1 A sufficient number of skilled supervisors is to be provided to ensure an effective and systematic control at all stages of welding operations.

3.7.2 Where structural components are to be assembled and welded in works sub-contracted by Builders, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

3.7.3 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations.

3.7.4 The location of welding connections and sequences of welding are to be arranged to minimise restraint. Welding joints are to be so arranged as to facilitate the use of down-hand welding wherever possible.

3.7.5 All welding is to be carried out in accordance with the approved welding procedure, *see* 3.6. The welding arrangements and sequence are to be in accordance with the approved plans and agreed with the Surveyor prior to construction.

3.7.6 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members, including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimise angular distortion of the stiffener.

3.7.7 The surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. Where manual arc welding is used, each run of deposit is to be effectively clean and free from slag before the next run is applied. Before a sealing run is applied to the back of the weld, the root is to be back chipped, ground or air-arc gouged to sound metal. With other multi-run welding processes back gouging before the application of a sealing run may not be necessary. When air-arc gouging is used for this operation, special care is to be taken to ensure that the ensuing groove is slag free and has a profile suitable for the completion of welding.

3.7.8 Where prefabrication primers are applied over areas which will be subsequently welded, they are to be of a quality acceptable to LR as having no significant deleterious effect on the finished weld, *see* Vol 1, Pt 6, Ch 6,2.6.

3.7.9 All joints are to be properly aligned and closed or adjusted before welding. Excessive force is not to be used in fairing and closing the work. Where excessive gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyor. Provision is to be made for retaining correct alignment during welding operations. Clamps with wedges or strong-backs used for this purpose are to be suitably arranged to allow freedom of lateral movement between adjacent elements.

3.7.10 Tack welds are to be kept to the minimum and are to be made in accordance with the approved welding procedure. Tack welds which are to be retained as part of the finished weld are to be clean and free from defects. Care is to be taken when removing tack welds used for assembly to ensure that the material of the structure is not damaged.

3.7.11 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and 50 mm for higher tensile steel grades.

3.7.12 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not only restricted to the positions where eye plates have been removed but should also includes the positions where lifting eye plates are permanent fixtures.

3.7.13 Welded temporary attachments used to aid construction are to be removed carefully by grinding or cutting. The surface of the material is to be finished smooth by grinding followed by crack detection.

3.7.14 Where complete removal of lifting lug attachments is required, it is recommended they be burned off at the top of the fillet weld connections and the remainder chipped and ground smooth. However, alternative methods of removing these attachments will be considered.

3.7.15 Any defects in the structure resulting from the removal of temporary attachments are to be repaired.

3.7.16 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding should also be subject to non-destructive examination.

3.7.17 Fairing, by linear or spot heating, to correct distortions due to welding, is to be carried out using approved procedures in order to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from cracking.

3.7.18 All major welding operations should be complete prior to final machining operations on, for example, rudders sterntubes, propeller brackets and jet units.

3.7.19 Preheating is to be applied in accordance with the approved procedure. When the ambient temperature is below 5°C or where moisture resides on the surface to be welded, due care should be taken to prewarm and dry the joint preparation.

3.7.20 Adequate protection is to be provided where welding is required to be carried out in exposed positions in wet, windy or cold weather.

3.7.21 Special attention is to be paid to preheating when low hydrogen electrodes are used for higher tensile steels on thick materials under high restraint or when applying small weld beads.

3.8 Inspection

3.8.1 Effective arrangements are to be provided by the Shipbuilder for the visual inspection of all finished welds in order to ensure that all welding has been satisfactorily completed.

3.8.2 Welds are to be clean and free from paint at the time of visual inspection.

3.8.3 Welds may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defect areas.

3.8.4 All finished welds are to be of an acceptable quality in accordance with 3.9.

3.8.5 Visual examination of all the welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary by the Surveyor.

3.8.6 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

3.8.7 Typical locations for volumetric examination and number of checkpoints to be taken are as shown in Table 6.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.8.8 The method to be used for the volumetric examinations of welds is the responsibility of the Shipbuilder. Radiography is generally preferred for the examination of butt welds of 15 mm thickness or less. Ultrasonic testing is acceptable for welds of 15 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration.

3.8.9 Non-destructive examinations are to be made in accordance with approved written procedures prepared by the Shipbuilder, which identify the method and technique to be used, the extent of the examination and the acceptance criteria to be applied.

Table 6.3.1 Recommended extent of NDE checkpoints

Volumetric non-destructive examinations – recommended extent of testing, *see* 3.8.15		
Item	Location	Checkpoints (*see* Note 1)
Intersections of butts and seams of fabrication and section welds	Throughout: (a) The hull envelope plating: • at critical locations identified by FDA, *see* Note 2 • at other highly stressed areas, *see* Note 3 • remainder (b) longitudinal and transverse bulkheads (c) inner bottom	 All All 1 in 2 1 in 2 1 in 2
Butt welds in plating	Throughout	1 m in 25 m, (*see* Notes 4 and 5)
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: sheerstrake to deck stringer plate or angle	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. FDA signifies the fatigue design assessment procedure.
3. Typically those at shear strake, deck stringer, keel strake and turn of bilge.
4. Checkpoints in butt welds and seam welds are in addition to those at intersections.
5. Welds at inserts used to close openings in hull envelope plating are to be checked by non-destructive examination.
6. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
7. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects such as lack of fusion or incomplete penetration are repeatedly observed.

3.8.10 Non-destructive examinations are to be undertaken by personnel qualified to the appropriate level of a certification scheme recognized by LR.

3.8.11 Checkpoint examinations at the sub-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.8.12 Checkpoint examinations at the construction stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the Shipbuilder. The locations and numbers of checkpoints are to be agreed between the Shipbuilder and the Surveyor.

3.8.13 Where components of the structure are sub-contracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the shipyard. In these cases, particular attention is to be given to highly loaded fabrications (such as stabilizer fin boxes) forming an integral part of the hull envelope.

3.8.14 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at the ends of fillet welds, T-joints, joints or crossing in main structural members.

3.8.15 Checkpoints for volumetric examinations are to be selected so that a representative sample of all types of weld are examined.

3.8.16 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperature, the extent of non-destructive examination will be specially considered.

3.8.17 For all ship types, the Shipbuilder is to carry out random non-destructive examination at the request of the Surveyor.

3.8.18 The full extent of any weld defect is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and where necessary, re-welded. The repair is to be examined after re-welding by the same method used to detect the defect.

3.8.19 Results of non-destructive examinations made during construction are to be recorded and evaluated by the Shipbuilder on a continual basis in order that the quality of welding can be monitored. These records are to be made available to the Surveyor.

3.8.20 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

3.9 Acceptance criteria

3.9.1 All finished welds are to be sound and free from cracks, lack of fusion, incomplete penetration, and substantially free from porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided. Details of weld defect levels are given in the Naval Survey Guidance for Steel Ships.

3.10 Weld repair

3.10.1 Repairs to defective welding are to be carried out using approved welding consumables and procedures. The repair is to be re-examined.

3.10.2 Major repairs should not be carried out without prior approval of the Surveyor.

3.10.3 Repairs to defects found in the base materials during construction should not be carried out without prior approval of the Surveyor. If repairs are agreed these should be carried out in accordance with the requirements of the relevant section of Part 2, using qualified welding procedures.

3.10.4 When misalignment of structural members either side of bulkheads, decks, etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and rewelded in accordance with an approved weld repair procedure.

■ *Section 4*
Welded joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, rivetting of light structure and adhesive bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:

(a) Weld throat thickness or leg lengths.
(b) Grades, tempers and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Welded connections to steel castings, *see* 3.7.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be included in the approval welding procedure.

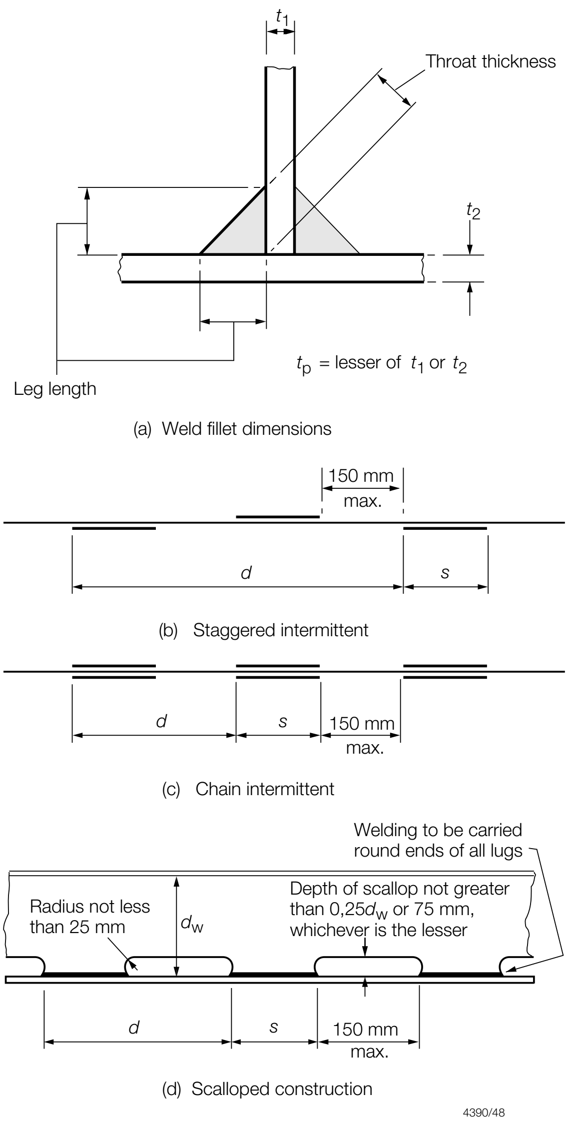
4.4.2 Abrupt changes of section are to be avoided where plates of different thicknesses are to be butt welded. Where the difference in thickness exceeds 3 mm, the thicker plate to be welded is to be prepared with a taper not exceeding one in three or with a bevelled edge to form a welded joint proportioned correspondingly. Where the difference in thickness is less than 3 mm the transition may be achieved within the width of the weld. Difference in thickness greater than 3 mm may be accepted provided it can be proven by the Builder, through procedure tests, that the Rule transition shape can be achieved and that the weld profile is such that structural continuity is maintained to the Surveyor's satisfaction. For ships with shock enhanced notation, *see* Pt 4, Ch 2.4.

4.4.3 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these welds are to be made flush in way of the faying surface. Similarly, for butt welds in webs of stiffening members, the butt weld is to be completed and generally made flush with the stiffening member before the fillet weld is made. The ends of the flush portion are to run out smoothly without notches or sudden change of section. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member. Scallops are to be of such size, and in such a position, that a satisfactory weld can be made, *see* Pt 3, Ch 2,3.

4.4.4 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.5 Fillet welds

4.5.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 6.4.1. Where the connection is highly stressed full penetration welding may be required. Where full penetration welding is required, the abutting plate may need to be bevelled.



NOTE *s* to be not less than 75 mm, in all cases

Fig. 6.4.1 Weld types

4.5.2 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6

Weld factors are contained in Table 6.4.1 and Fig. 6.4.1.

NOTE: for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1, *see* 4.8.1.

4.5.3 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, *see* Fig. 6.4.2.

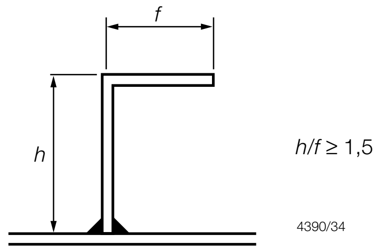


Fig. 6.4.2 Web height/flange breadth ratio

4.5.4 Where an approved automatic deep penetration procedure is used, the weld factors given in Table 6.4.1 may generally be reduced by 15 per cent. Consideration may be given to reductions of up to 20 per cent.

4.5.5 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.6 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.5.7 Where the thickness of the abutting member of the connection (e.g. the web of a stiffener) is greater than 15 mm and exceeds the thickness of the table member (e.g. plating), the welding is to be double continuous and the throat thickness of the weld is to be not less than the greatest of the following:

(a) 0,21 x thickness of the table member. The table member thickness used need not exceed 30 mm.
(b) 0,21 (0,27 in tanks) x half the thickness of the abutting member.
(c) As required by Item 3 in Table 6.4.2.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 6.4.2 are to be complied with.

4.7 Single sided welding

4.7.1 Where the main welding is carried out from one side only, this should be in accordance with the approved single sided welding procedure.

4.7.2 Where internal access for welding is impracticable, backing bars are to be fitted in way of butt welds, or alternative means of obtaining full penetration welds are to be agreed. Backing bars may be permanent or temporary, subject to agreement.

Table 6.4.1 Weld factors (*see continuation*)

Item	Weld factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners, etc.	0,10	
Overlap welds generally	0,27	
Longitudinals of the flat-bar type to plating		*See* 4.5.7
(2) Bottom construction in way of tanks:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals or reverse frames	0,13	
Connection of floors to inner bottom in way of bulkheads, supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	weld size based on floor thickness weld material compatible with floor material *See* Note 4
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
Tank side brackets to shell and inner bottom	0,34	
(4) Decks and supporting structure:		
Strength deck plating to shell		as shown in Table 6.4.5 but alternative proposals will be considered
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	 *see* Note 1
Girder web connections and brackets in way of pillar heads and heels and end brackets	0,21	continuous
Girder web connections general	0,1	

Table 6.4.1 Weld factors (*continued*)

Item	Weld factor	Remarks
(5) Bulkheads and tank construction:		
Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead plating Weld material to be compatible with bulkhead plating material
Shelf plate connection to stool	0,44	Weld size to be based on thickness of stool at junction with shelf plate. Weld material to be compatible with stool material
Plane, double plate and corrugated main watertight bulkhead boundaries – Boundary at bottom, bilge, inner bottom and deck – Connection of bulkhead plating to side shell	0,44 0,44	
Deep tank horizontal boundaries at vertical corrugations	Full penetration	
Secondary members where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
(6) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(7) Construction in 0,25*L* forward:		
Floors and girders to shell and inner bottom	0,21	
Bottom longitudinals to shell	0,13	
Transverse and longitudinal side framing to shell	0,13	
Tank side brackets to frame and inner bottom	0,34	
Panting stringers to shell and frames	0,34	
Fore peak construction: all internal structure	0,13	unless a greater weld factor is required
(8) After peak construction: All internal structure and stiffeners on afterpeak bulkhead	0,21	unless a greater weld factor is required
(9) Superstructure and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	

Table 6.4.1 Weld factors (*conclusion*)

Item	Weld factor	Remarks
(10) Steering control systems:		
Rudder:		
Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles:		
Main structure	0,44	
Elsewhere	0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.:		
Main structure	0,44	
Elsewhere	0,21	
(11) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipe, etc., coamings to deck	0,34	
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, derrick posts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	Continuous fillet weld,minimum throat thickness 3 mm
Fabricated anchors	full penetration	
Machinery rafts		
Raft seatings		
Weapon seatings		
NOTE Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2.		

Table 6.4.2 Throat thickness limits

Item	Throat thickness, in mm Minimum	Throat thickness, in mm Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) All welds, overriding minimum:		
(a) Plate thickness $t_p \leq 7{,}5$ mm		
Hand or automatic welding	3,0	–
Automatic deep penetration welding	3,0	–
(b) Plate thickness $t_p > 7{,}5$ mm		
Hand or automatic welding	3,25	–
Automatic deep penetration welding	3,0	–

NOTES
1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above.
2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to $0{,}5\,(t_p + 25)$ mm.
3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the surveyors satisfaction.

4.7.3 Permanent backing bars are to be of the same material as the base metal and of thickness not less than the thickness of the plating being joined or 4 mm, whichever is the lesser. The weld is to be thoroughly fused to the backing bar subject to agreement.

4.7.4 Backing bars are to be continuous for the full length of the weld and joints in the backing bar are to be by full penetration welds, ground smooth.

4.7.5 Temporary backing bars for single sided welding may be, glass tape, ceramic, or steel of the same grade as the base metal.

4.7.6 Temporary non-metallic backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking *d/s* equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:
(a) Boundaries of weathertight decks and erections and all other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine and equipment seatings and rafts.
(d) Bottom framing structure in machinery spaces of high speed ships.
(e) The side and bottom shell structure in the impact area of high speed ships.
(f) Structure in way of rudders, propeller brackets, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(g) The shell structure in the vicinity of the propeller blades.
(h) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(j) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.
(k) All structure in the after peak and after peak bulkhead stiffeners.
(l) Forward tanks.
(m) Lap welds in tanks.
(n) Primary and secondary members to bottom shell forward of 0,7*L*.
(o) Where 4.5.7 applies.
(p) Other connections or attachments where necessary in particular minor items to high tensile steel plating.
(q) Fillet welds where high tensile steel is used.

4.9 Intermittent welding (staggered and chain)

4.9.1 The requirements for intermittent welding are given in Fig. 6.4.1.

4.9.2 Where staggered intermittent welding is used, the welding is to be made continuous round the ends of brackets, lugs, scallops, etc.

4.9.3 Staggered intermittent welding is not to be used in the bottom shell structure of high speed ships.

4.9.4 Chain intermittent welding may be used, outside of the impact area in the bottom shell structure of high speed ships.

4.9.5 Scalloped construction or intermittent welding is not be used in structure on or below the strength deck of ships with shock enhancement or in structure strengthened for blast enhancement, *see* Pt 4, Ch 2.

4.9.6 Intermittent welding or scalloped construction is not to be used in structure complying with the requirements of the internal blast station.

4.9.7 For ships with a shock enhanced notation, the extent of intermittent welding will be specially considered on the basis of the sweat levels.

4.10 Slot welding

4.10.1 For the connection of plating to internal webs where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds, or by slot fillet welds to face plates fitted to the webs. Slots are, in general, to have a minimum length of ten times the plating thickness or 75 mm, whichever is the lesser, but in no case to be taken as less than 40 mm, and a minimum width of twice the plating thickness or 15 mm whichever is the greater, with well rounded ends. Slots cut in plating are to

have smooth, clean and flat edges and the distance between the slots is, in general, not to exceed 150 mm. Slots are not to be filled with welding. Alternative proposals for length, width and spacing of slot welds will be specially considered. For rudder closing plates, *see* Pt 3, Ch 3,2.18.4.

4.11 Stud welding

4.11.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be tested to the satisfaction of the Surveyors.

4.12 Lap connections

4.12.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. Where, however, plate overlaps are adopted, the width of the overlap is not, in general to exceed four times nor be less than three times the thickness of the thinner plate and the joints are to be positioned so as to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

4.13 Connections of primary structure

4.13.1 Weld factors for the connections of primary structure are given in Table 6.4.3.

4.13.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0,85 \text{ x stiffener spacing}}{\text{length of web plating between notches}}$$

4.13.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.13.4 The throat thickness limits given in Table 6.4.2 are to be complied with.

4.13.5 Where a margin angle is not fitted the sheerstrake connection is to be in accordance with Table 6.4.5.

4.14 Primary and secondary member end connection welds

4.14.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.14.2 The welding of secondary member end connections is to be not less than as required by Table 6.4.4. Where two requirements are given the greater is to be complied with.

Table 6.4.3 Connections of primary structure

Primary member face area, in cm^2		Position (1)	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends Remainder	0,21 0,10	0,27 0,16	0,21 0,10	0,21 0,13
30,0	65,0	At ends Remainder	0,21 0,13	0,34 0,27	0,21 0,13	0,21 0,16
65,0	95,0	At ends Remainder	0,34 0,27 (2)	0,44 (3) 0,34	0,21 0,16	0,27 0,21
95,0	130,0	At ends Remainder	0,34 0,27 (2)	0,44 (3) 0,34	0,27 0,21	0,34 0,27
130,0		At ends Remainder	0,44 0,34	0,44 (3) 0,34	0,34 0,27	0,44 (2) 0,34

NOTES
1. The weld factors 'at ends' are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.
2. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.
3. The weld factor of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads all in the lower half depth, is to be not less than 0,34.
4. The final throat thickness of the weld fillet to be not less than $0,34t_p$ in oil tanks.

Table 6.4.4 Primary and secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) in 0,15L forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that be greater	—	0,34
Symbols		
A_s = cross sectional area of the stiffener, in cm^2 A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based.		
NOTE For maximum and minimum weld fillet sizes, *see* Table 6.4.2.		

4.14.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.14.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.14.5 The scantlings of brackets are to be in accordance with Pt 6,as appropriate.

4.14.6 The throat thickness limits given in Table 6.4.2 are to be complied with.

4.15 Tank boundary penetrations

4.15.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

4.16 Intersection of primary and secondary members

4.16.1 The weld area of the connections is to be generally not less than the following:

(a) Connection of primary member stiffener to the secondary member:

A_w = $0{,}25A_f$ or 6,5 cm^2, whichever is the greater, corresponding to a weld factor of 0,34 for the throat thickness

(b) Connection of secondary member to the web of the primary member:

A_w = $0{,}5\sqrt{Z}$ corresponding to a weld factor of 0,34 in tanks or 0,27 in dry spaces for the throat thickness.

where

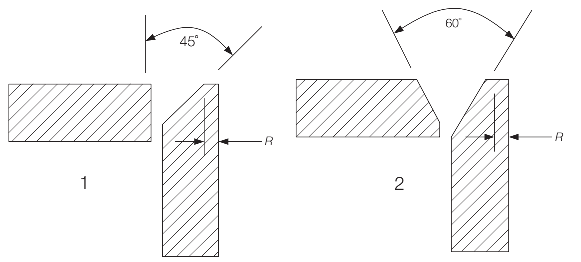
A_w = weld area, in cm^2, and is calculated as total length of weld, in cm, multiplied by throat thickness, in cm

A_f = cross-sectional area of the primary member web stiffener, in cm^2, in way of connection

Z = the section modulus, in cm^3, of the secondary member.

Table 6.4.5 Weld connection of strength deck plating to sheerstrake

Item	Stringer plate thickness, mm	Weld type
1	$t \leq 15$	Single vee preparation to provide included angle of 45° with root $R \leq \frac{1}{3}t$ in conjunction with a continuous fillet weld having a weld factor of 0,39
2	$15 < t \leq 25$	Double vee preparation to provide included angle of 60° with root $R \leq \frac{1}{3}t$ in conjunction with a continuous fillet weld having a weld factor of 0,39
3	$t > 25$	Triple vee preparation to provide included angles of 50° with root R $\frac{1}{3}t$ but not to exceed 10 mm



NOTES
1. Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.
2. *See also* 4.16.1.
3. For thickness t in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.
4. Alternative connections will be considered.

■ *Section 5* Construction details

5.1 Continuity and alignment

5.1.1 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate or brackets are to be fitted, *see* Fig. 6.5.1.

5.1.2 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off.

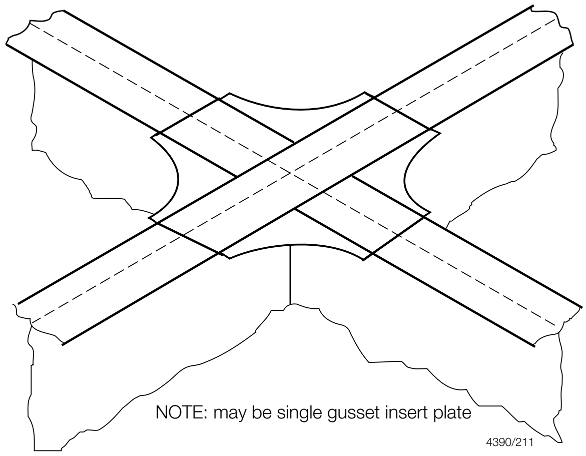


Fig. 6.5.1 Primary member intersection

5.1.3 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 6.5.2.

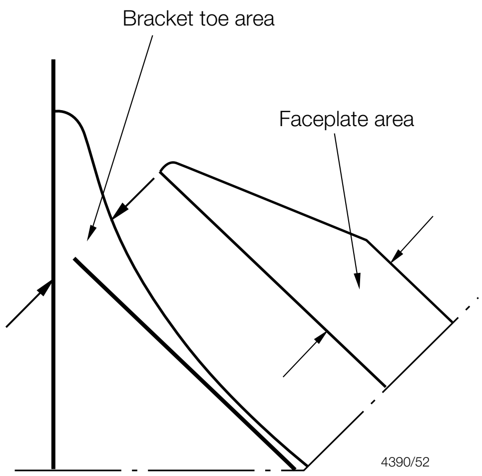


Fig. 6.5.2 Bracket toe construction

5.2 Primary end connections

5.2.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all ship types are generally to comply with the requirements of Ch 2,3, taking Z as the section modulus of the primary member.

5.2.2 Guidance on the arrangement of primary stiffeners is given in Pt 3 Ch 2,3.2.

5.2.3 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

5.2.4 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

5.2.5 The geometric properties of the members are to be calculated in association with an effective width of attached plating determined in accordance with Ch 2,2.2.

5.2.6 The minimum thickness or area of material in each component part of the primary member is given in Table 6.5.1.

Table 6.5.1 Minimum thickness of primary members

Item	Requirement
(1) Member web plate (*see* Note)	$t_w = 0{,}01S_w$ but not less than 6 mm in dry spaces and not less than 7 mm in tanks
(2) Member face plate	A_f not to exceed $\dfrac{d_w\, t_w}{150}$ cm^2
(3) Deck plating forming the upper flange of underdeck girders	Plate thickness not less than $\sqrt{\dfrac{A_f}{1{,}8k}}$ mm
Symbols	
d_w = depth of member web, in mm k = higher tensile steel factor, *see* Ch 2 t_w = thickness of member web, in mm A_f = area of member face plate or flange, in cm^2 S_w = spacing of stiffeners on member web, or depth of unstiffened web, in mm	
NOTE For primary members having a web depth exceeding 1500 mm, the arrangement of stiffeners will be individually considered, and stiffening parallel to the member face plate may be required.	

5.3 Arrangement at intersection of primary and secondary members

5.3.1 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of equipment supports, bollards, fenders, etc.).

5.3.2 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

5.3.3 Cut outs in primary members are to comply with the requirements of Pt 3, Ch 2,3.2.11 and 3.2.12.

5.3.4 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress. Some typical lug connections are shown in Fig. 6.5.3 and Fig. 6.5.4, *see* 5.3.12.

5.3.5 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 20 mm, whichever is the greater. For large cut-outs greater than 250 mm deep, it is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 6.5.4, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

5.3.6 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

5.3.7 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

5.3.8 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

5.3.9 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of A_f, *see* 4.16.1.

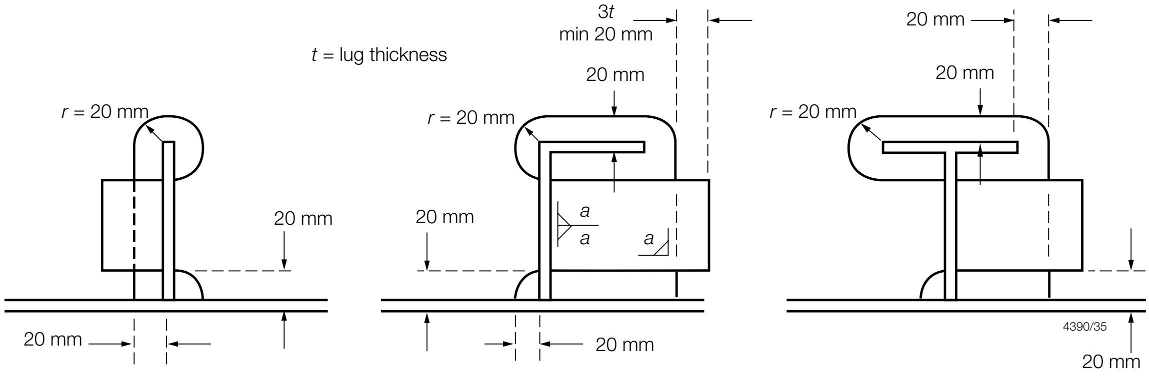


Fig. 6.5.3 Typical lug connections

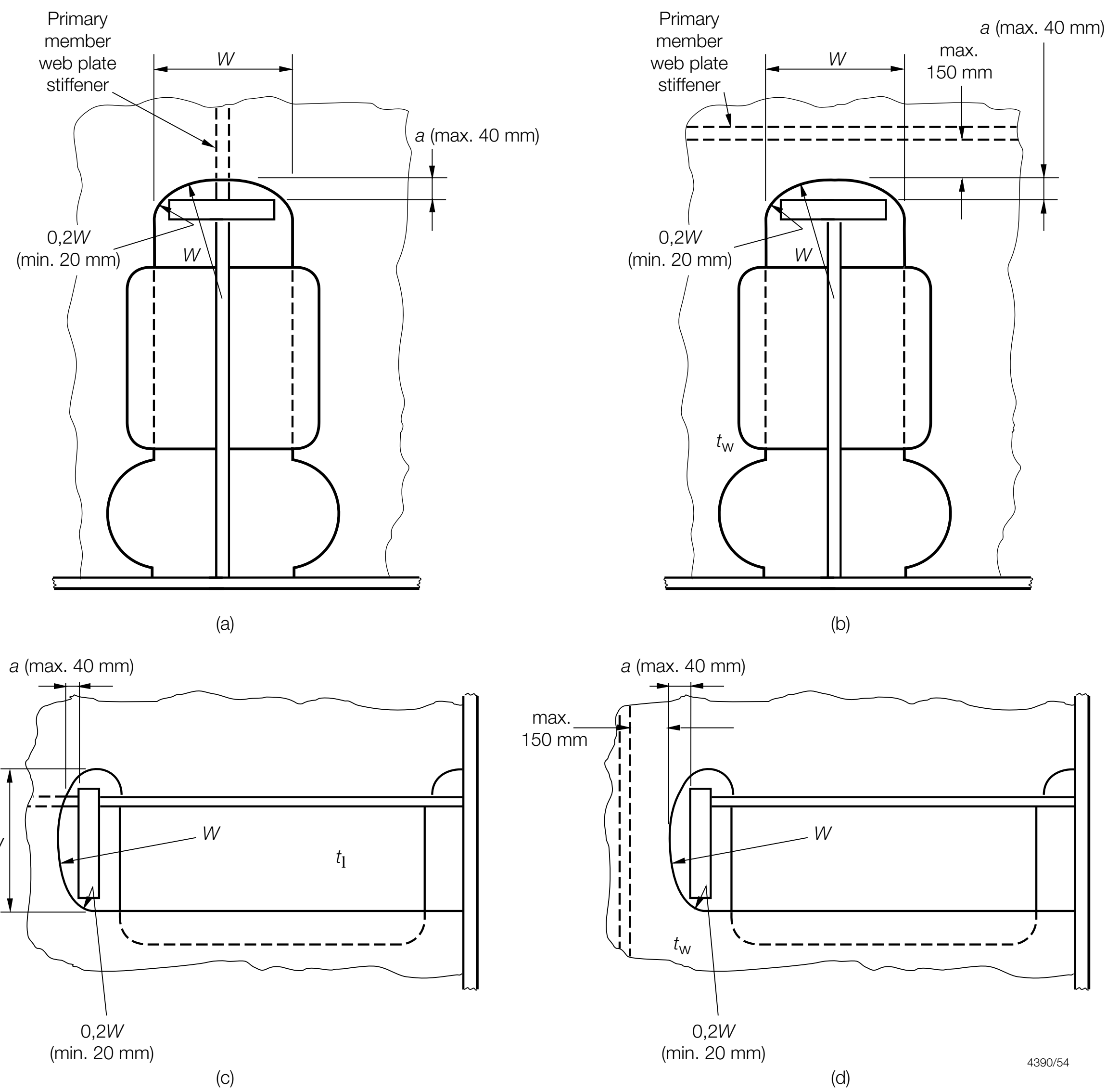


Fig. 6.5.4 Cut-out and connections

5.3.10 In general where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped. Lapped connections of primary member stiffeners to mild steel bulb plate or rolled angle secondary members may also be permitted. Where such lapped connections are fitted, particular care is to be taken to ensure that the primary member stiffener wrap around weld connection is free from undercut and notches, *see also* 3.8.

5.3.11 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing brackets on the opposite side of the transverse web or bulkhead. The primary member stiffener and backing brackets are to be lapped to the longitudinal web, *see* 5.3.10.

5.3.12 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with the appropriate permissible stress given in Table 6.5.2.

Table 6.5.2

Item	Direct stress N/mm	Shear stress N/mm
Primary web plate stiffener adjacent to connection with secondary member	157	—
Welded connection of primary member web plate stiffener to secondary member:		
Double continuous fillet	117,7	—
Automatic deep penetration	157	—
Lug or collar plate and weld connection	—	98,1

5.4 Arrangement with offset stiffener

5.4.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see* Fig. 6.5.5) the collar arrangement for the secondary members are to satisfy the requirements of 5.3.4. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

5.4.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

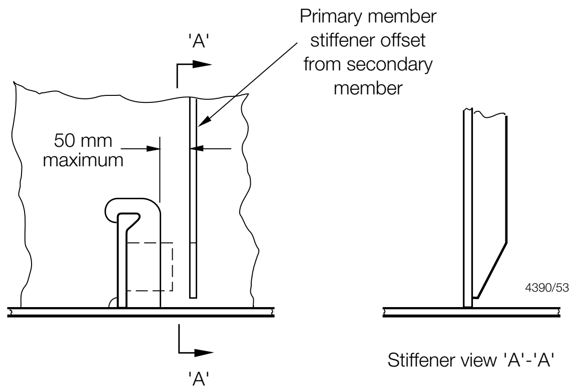


Fig. 6.5.5 Arrangement with offset stiffener

5.4.3 For ships with shock enhancement notation, *see* Pt 4, Ch 2,4.

5.5 Watertight collars

5.5.1 Watertight steel collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries.

5.5.2 Watertight steel collars or equivalent are to be fitted at gastight boundary.

5.6 Insert plates

5.6.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

5.6.2 The corners of insert plates are generally to be suitably radiused.

5.6.3 For ships with shock enhancement, *see* Pt 4, Ch 2.

5.7 Doubler plates

5.7.1 Doubler plates are to be avoided and are not to be fitted in areas where corrosion may be a problem and access for inspection and maintenance is limited.

5.7.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

5.8 Other fittings and attachments

5.8.1 Gutterway bars and spurnwaters are not to be welded to boundary angles, or within 100 mm of the deck edge.

5.8.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

5.8.3 Where necessary in the construction of the ship, lifting lugs may be welded to the hull plating but they are not to be slotted through. For removal, *see* 3.7.14.

5.9 Bilge keels and ground bars

5.9.1 Bilge keel plating is to be attached to the shell plating as shown in Fig. 6.5.6. Butt and seam welds in shell plating and bilge keels are to be staggered by at least 100 mm.

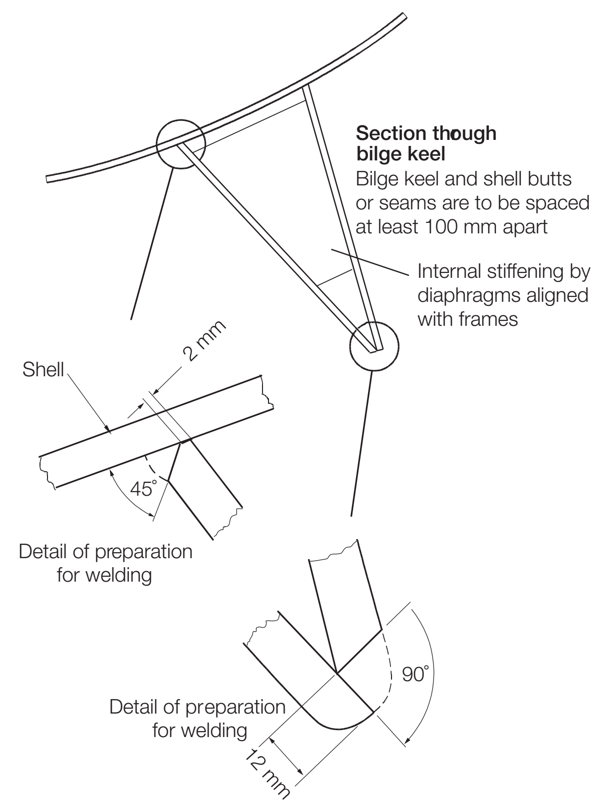


Fig. 6.5.6 Double plate bilge keel construction

5.9.2 The shell plating in way of the bilge keel is to be at least grade D. Insert plates of 50 per cent greater thickness than the as fitted surrounding shell plate are to be fitted. They are to be greater than 300 x 300mm^2 with well rounded corners.

5.9.3 The thickness of the bilge keel is to be assessed using the appropriate scantling equation for shell envelope plating. To prevent possible damage to the shell, the bilge keel plate is not to be thicker than the adjacent shell plate. The material class, grade and quality of the bilge keel plating is to be the same as the adjacent shell plating, *see* Table 6.2.1.

5.9.4 Full continuous welding is to be used to connect the bilge keel to the shell.

5.9.5 The ends of the bilge keels are to be have a 1 in 3 taper and terminate within 300 mm to 100 mm past an internal frame. Suitable internal framing is to be arranged in way of the ends of the bilge keels where, for hydrodynamic reasons, a steeper taper is necessary, the termination of the bilge keels will be especially considered.

5.9.6 For ships over 65 m in length, all welds are to be subject to non-destructive examination.

5.9.7 Bilge keels of an alternative design from that shown in Fig. 6.5.6 with single plate construction or fitted with ground bars will be specially considered.

5.9.8 Internal stiffening is to be arranged in line with hull framing but is not to be attached to the shell plating.

5.9.9 Bilge keels are to be watertight and tested in accordance with Section 6.

5.9.10 The internal surfaces of the bilge keel and stiffening are to be suitably protected against corrosion.

5.10 Rivetting of light structure

5.10.1 Where it is proposed to adopt rivetted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate rivetting schedule is to be submitted.

5.10.2 Samples may be required of typical rivetted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

5.10.3 Where rivetting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

5.10.4 Where two dissimilar metals are to be joined by rivetting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

5.10.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

5.10.6 Sealing paints or compounds are not to be used with hot driven rivets.

5.11 Adhesive bonding of structure

5.11.1 Where adhesive bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance of a typical joint.

5.11.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

5.11.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

5.11.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

5.11.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be developed. Air pockets are to be avoided.

5.11.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

5.12 Triaxial stress considerations

5.12.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design.

5.13 Aluminium/steel transition joints

5.13.1 Provision is made in this Section for bi-metallic composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Pt 2, Ch 8,4.

5.13.2 Where a manufacturer is not approved, details of the materials to be used and the manufacturing procedures are to be submitted for approval before use.

5.13.3 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

5.13.4 Control of heat input is required when welding the transition joints to the steel structure in order to prevent disbondment.

5.14 Steel/wood connection

5.14.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

■ *Section 6*
Inspection and testing procedures

6.1 General

6.1.1 A structural and leak test plan is to be submitted defining the compartments or tanks to be tested and the method of testing in accordance with the requirements of this Section.

6.1.2 Although referred to as watertight, some compartments or tanks may require to be tested as gastight or oil tight.

6.1.3 The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in Table 6.6.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired by subsequent work.

6.2 Definitions

6.2.1 For the purpose of these procedures the following definitions apply:

(a) Protective coating is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.
(b) Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing (*see* (e)) may be carried out instead.
(c) Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.
(d) Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.
(e) Hydropneumatic testing is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 6.5.

Table 6.6.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: — head of water up to the top of the overflow — head of water representing the maximum pressure experienced in service for which elastic design criteria were used.
Cofferdams	Structural (1)	The greater of: — head of water up to the top of the overflow — 1,8 m head of water above highest point of tank (4)
Forepeak and aft peak used as tank (3)	Structural	
Tank bulkheads	Structural (1)	The greater of: — head of water up to the top of the overflow — 1,8 m head of water above the highest point of tank (4) — setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Fuel oil tanks	Structural	
Scupper and discharge pipes in way of tanks	Structural (1)	
Sea inlet boxes	Structural (1) Sonar domes	— head of water up to the damage control deck/ vee line
Speed and depth instrument compartments	Structural (1)	— head of water up to the damage control deck/ vee line — top of the header tank
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Double plate bilge keels	Structural (1)	— head of water up to the design waterline
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 6.6
Watertight doors and hatches (below the vertical limit of watertight integrity) when fitted in place	Hose (6)	
Weathertight hatch covers and closing appliances	Hose	
Fore peak not used as tank	Hose (2)	
Shell doors	Hose	
Chain locker, if aft of collision bulkhead	Structural	Head of water up to the top of the overflow pipe
Independent/Separate fuel oil tanks Filling trunks	Structural	Head of water representing the maximum pressure which could be experienced in service for which elastic design criteria were used, but not less than 3,5 m
After peak not used as tank	Leak	*See* 6.5
Magazines	Leak (6) (7)	*See* 6.5

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design, *see* 6.7.
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Where applicable testing of the aft peak is to be carried out after the stern tube has been fitted.
4. The highest point of the tank is generally to exclude hatchways.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. If a flooding arrangement is used the structure is to be tested using the maximum head that could be experienced for which elastic design criteria were used.
7. If the magazine is required to contain an overpressure, for example due to a fire, the testing requirements are to be specified by the Naval Authority.

6.3 Testing arrangements

6.3.1 For tank and compartment penetrations not fitted with closing devices adjacent to the boundary, temporary closing devices are to be provided and stowed near to the penetration for periodic testing by ships staff.

6.3.2 The testing of watertight doors, hatches and similar fittings are to be tested in such a manner as to force them off their seatings.

6.3.3 Bathrooms are to be tested with a flood to the level of the sill.

6.3.4 All Scupper soil and urinal pipes are to be tested to the maximum head experienced in service.

6.3.5 All piping systems are to be tested in accordance with Vol 2, Pt 7,1.16.

6.4 Structural testing

6.4.1 Generally all tanks or compartments that carry liquid in bulk are to be structurally tested at build.

6.4.2 Where it is intended to carry out structural tests after the protective coating has been applied welds are to be leak tested prior to the coating application.

6.4.3 For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating during the test is to be ascertained, and any deficiencies repaired.

6.4.4 Compartments to be tested are to be structurally complete and all fittings which affect the watertight integrity of the compartment such as doors, hatches, manholes, penetrations, valves and glands are to be fitted.

6.4.5 In compartments containing the stabiliser fins, rudder stocks, sonar hull outfit, echo sounders, etc., the bearing houses are to be installed and the seating arrangements completed before testing.

6.4.6 Arrangements are to be provided to ensure the free passage of air from the top of the tank tested. The air pipe or indicator test plug may be used for this purpose.

6.4.7 Where necessary additional temporary support are to be fitted to the hull to prevent excessive deformation.

6.4.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 6.6.1. An internal inspection of the tanks is to be made whilst the ship is afloat.

6.4.9 Where permitted by Table 6.6.1, complete structural testing may be replaced by a combination of leak and structural testing, as follows: The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth:

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.
(b) All deep tanks are to be structurally tested.
(c) Interconnecting deep and double bottom tanks and ‘flume’ type stabilisation tanks are to be structurally tested to the test head given in Table 6.6.1.

6.4.10 Equivalent proposals for testing will be considered.

6.4.11 It is recommended that a leak test in accordance with 5.5 is carried out before the structural test commences to identify any leak paths which may compromise the structural test.

6.5 Leak testing

6.5.1 Generally all boundaries for watertight subdivision are to be given a leak test when structural work is complete. The test is to be carried out before the compartment is fitted out and linings or covering applied.

6.5.2 Testing is to be carried out by applying an efficient indicating liquid, e.g. soapy water solution, to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

6.5.3 It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection.

6.5.4 A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a calibrated pressure gauge, or alternative equivalent system.

6.5.5 Leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, except welds made by automatic processes and on all outfitting penetrations.

6.5.6 Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor.

6.6 Hose testing

6.6.1 Hose testing is to be carried out on all structure that is required to be weathertight and has not been tested by structural or air testing.

6.6.2 Testing is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

6.6.3 The duration of hose testing is to be at the discretion of the surveyor. Leaks are to be marked, repaired and re tested until no water leakage it detected.

6.7 Hydropneumatic testing

6.7.1 When this is performed, the safety precautions identified in 6.5 are to be followed.

6.8 Gastight testing

6.8.1 Where gastight testing is requested by the Naval Authority the boundaries of citadels and zones defined in Pt 4, Ch 1,7 are to be tested for gas tightness using a pressure drop test. In addition, compartments containing noxious or explosive gases such as Acetone, Dope, Flammable stores, Oxygen, etc., are to be subject to a pressure drop test.

6.8.2 The test is to be carried out with compartment as near to completion as possible. Further work on a compartment after the test may result in a retest.

6.8.3 The pressure in the compartment is to be brought to 0,015 Bar (0,015 kgf/cm^2) (150 mm of fresh water) and the supply isolated. The fall in pressure after 10 minutes is not to be greater than 0.0013 Bar (0,0013 kgf/cm^2) (13 mm of fresh water).

6.8.4 A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe.

6.8.5 If the pressure drop specified in 5.9.2 the compartment is to be inspected for leaks and the test repeated until the specified standard is achieved.

6.8.6 In certain compartments that are not able to be made fully gas tight due to operational requirements, a greater fall in pressure may be accepted at the discretion of the surveyor. In no case is the pressure to drop more than 0,0075 Bar (0,0075 kgf/cm^2) (75 mm of fresh water) in 10 minutes from an initial 0,015 Bar (0,015 kgf/cm^2) (150 mm of fresh water).

6.8.7 Consideration will be given to the testing of adjacent boundaries or equivalent in those spaces which are not able to be closed such as gun rings and main machinery spaces.

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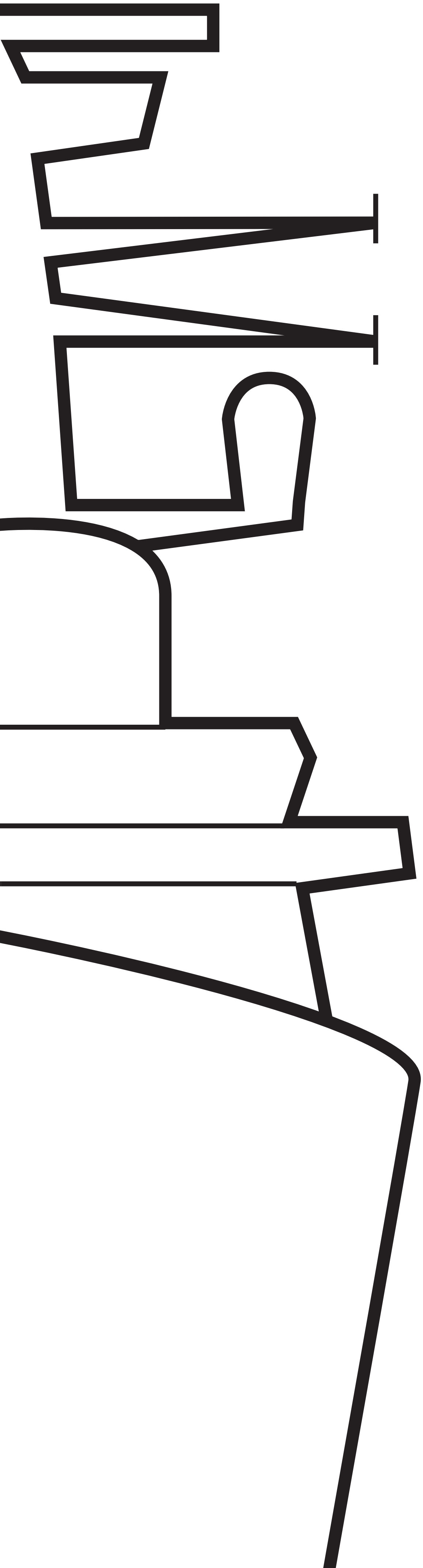


Rules and Regulations for the Classification of Naval Ships

Volume 1 *Part 7*

Enhanced Structural Assessment

January 2005

(PROVISIONAL)

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda. A dot-dash line indicates changes necessitated by International Conventions, Code of Practice or IACS Unified Requirements.

Rules programs

LR has developed windows based Rules Calculation Software which evaluates Rule Requirements for Special Service Crafts' structures. For details of this software please contact Lloyd's Register.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to Lloyd's Register's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2005

Chapter Contents

Volume 1, Part 7

Contents

■ *Section 1* General

1.1 Application

1.1.1 This Part gives the procedures that may be optionally applied for the structural design and assessment of all naval ships. Ships which comply with these requirements will be eligible to be assigned the additional class notations applicable to each procedure. The full list of class notations is given in Pt 1, Ch 2.

1.1.2 The requirements for the following additional class notations are included within this Part:

TLA Total Load Assessment.
SDA Structural Design Assessment.

■ *Section 2* Total Load Assessment, TLA

2.1 Total Load Assessment notation – TLA

2.1.1 The **TLA** procedure is an optional procedure and is applied on a voluntary basis.

2.1.2 The ship's structure is examined using a total load approach and stress analysis techniques.

2.1.3 The total load approach applies static, hydrodynamic and inertial load components to the structure making due allowance for the local structural configuration. These load components include global and local considerations. The approach includes load combination factors which enable the total design loads to take account of the appropriate phase relationships between the various load parameters, e.g. relative vertical motion and global bending moment.

2.1.4 The stress analysis techniques predict the total stresses acting in the structure as a consequence of the total loads. These techniques cover the assessment of stresses in either primary/secondary plating systems or grillage systems.

2.1.5 The resulting stresses are then checked against a set of design factors, which include stress, deflection and buckling requirements.

2.1.6 Due to the nature of the **TLA** approach it is possible to achieve the following:

(a) Allow the designer to examine different loading scenarios
(b) Optimise the structure towards particular design solutions

2.1.7 The **TLA** procedure is in addition to the normal Rule structural design approval requirements specified within Pt 6, Ch 3.

2.1.8 The requirements for the **TLA** method are given in Chapters 2 and 3. Chapter 2 contains the requirements for the total design loads to be applied to the structure, Chapter 3 contains the requirements for the stress analysis and verification to be performed using these loads.

■ *Section 3* Structural Design Assessment, SDA

3.1 Structural Design Assessment notation – SDA

3.1.1 The **SDA** procedure is an optional procedure and is applied on a voluntary basis when an Owner or designer seeks to increase confidence levels in the structural integrity of a ship.

3.1.2 The ship structure is to be examined using finite plate element methods to assess both the overall and detailed structural capability to withstand static and dynamic loadings.

3.1.3 The **SDA** procedure is in addition to the normal Rule structural design approval requirements specified within Pt 6, Ch 3.

3.1.4 The **SDA** procedure may be mandatory for very structurally complex ships. For complex ships, the ship designer is to supply outline details of the ship to Lloyd's Register at an early stage in the design in order that agreement can be reached on the appropriate level of analysis required.

3.1.5 Where applicable, the ship structure is to be examined for the structural capability to withstand dynamic loadings from partially filled tanks or the influence of thermal loadings.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter specifies the method by which the total design loads for the optional Total Load Assessment, **TLA**, approach are derived. The **TLA** approach is given in Chapter 3, an overview of the **TLA** approach is given in Ch 3,1 and illustrated in Fig. 3.1.1 in Chapter 3.

1.1.2 The total design loads derived in this Chapter are also to be used to form the basic load cases for the optional Structural Design Assessment, **SDA**, procedure, *see* Ch 1,3.1.

1.1.3 The total design loads are derived by combining the local and global design loads, defined in Pt 5, Ch 3 and Pt 5, Ch 4 respectively, using load combination factors. These loads represent typical maximum values of combined loads that are simultaneously applied to the structure of a ship.

1.1.4 The total design loads given in this Chapter are applicable to all naval ships which are operating in the displacement mode.

1.1.5 The total design loads for ships that are operating in the planing or non-displacement modes will need to be specially considered. The loads given here are applicable for these ships whilst they are operating in the displacement mode, i.e. in severe sea-states when planing is not possible.

1.2 Overview of total design loads

1.2.1 The total design loads to be applied to each structural item are to include the following load and pressure components where applicable:

- global hull girder stress due to vertical bending, σ_{hg} in N/mm^2, derived in accordance with Pt 6, Ch 4;
- global hull girder shear stress loads, τ_{hg} in N/mm^2, derived in accordance with Pt 6, Ch 4;
- local pressure loads, P in kN/m^2, where P is the appropriate design pressure value for each component;
- local transverse, LT, or vertical support, LV, loads, in kN;
- mass inertial forces, in kN;
- local shear force loads, in kN.

1.2.2 In addition to the above loads, it may be necessary to consider the effects of the following on the structural components:

- bending of primary structure supported by major bulkheads;
- bending of primary structure supported by the side shell or longitudinal bulkheads;
- lateral bending moments and shear forces;
- global and local torsional moments.

1.2.3 Most of the above load components include a dynamically fluctuating component due to ship motions, e.g. side shell pressure due to wave and ship motion. These loads will not all be maximum simultaneously, due to their cyclic nature and the phase relationship between load values. Consequently it is not necessary to apply the maximum values of all these load components to the structure at the same time. Section 3 gives a method of combining these loads in order that representative total design loads may be applied to the structure.

1.2.4 The method of deriving the Total Design Loads for each structural component is given in Sections 4 and 5. However, it remains the responsibility of the designer to ensure that the loads applied are representative.

1.2.5 Details of all the loads applied to each structural component are to be supplied to Lloyd's Register (hereinafter referred to as 'LR').

1.2.6 The major load components to be applied to, or reacted by, the structure are illustrated in Fig. 2.1.1.

1.3 Environmental conditions

1.3.1 The environmental conditions for the determination of the total design loads are to be based on the normal environmental design criteria specified in Pt 5, Ch 2,2.3 unless otherwise stated.

1.3.2 The standard values of wave height factor, f_{Hs}, and service area factor, f_s, given in Pt 5, Ch 3,1.2.2 and Pt 5, Ch 2,2.4 respectively are to be used for the total design loads unless otherwise stated. These factors may be adjusted for damaged loading conditions, residual strength analysis, **RSA**, or for special operating conditions, e.g. a deep draft condition for the recovery of amphibious vehicles in sheltered waters.

1.4 Direct calculations

1.4.1 Alternative methods of establishing the total design loads will be specially considered, provided that they are based on established codes or standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

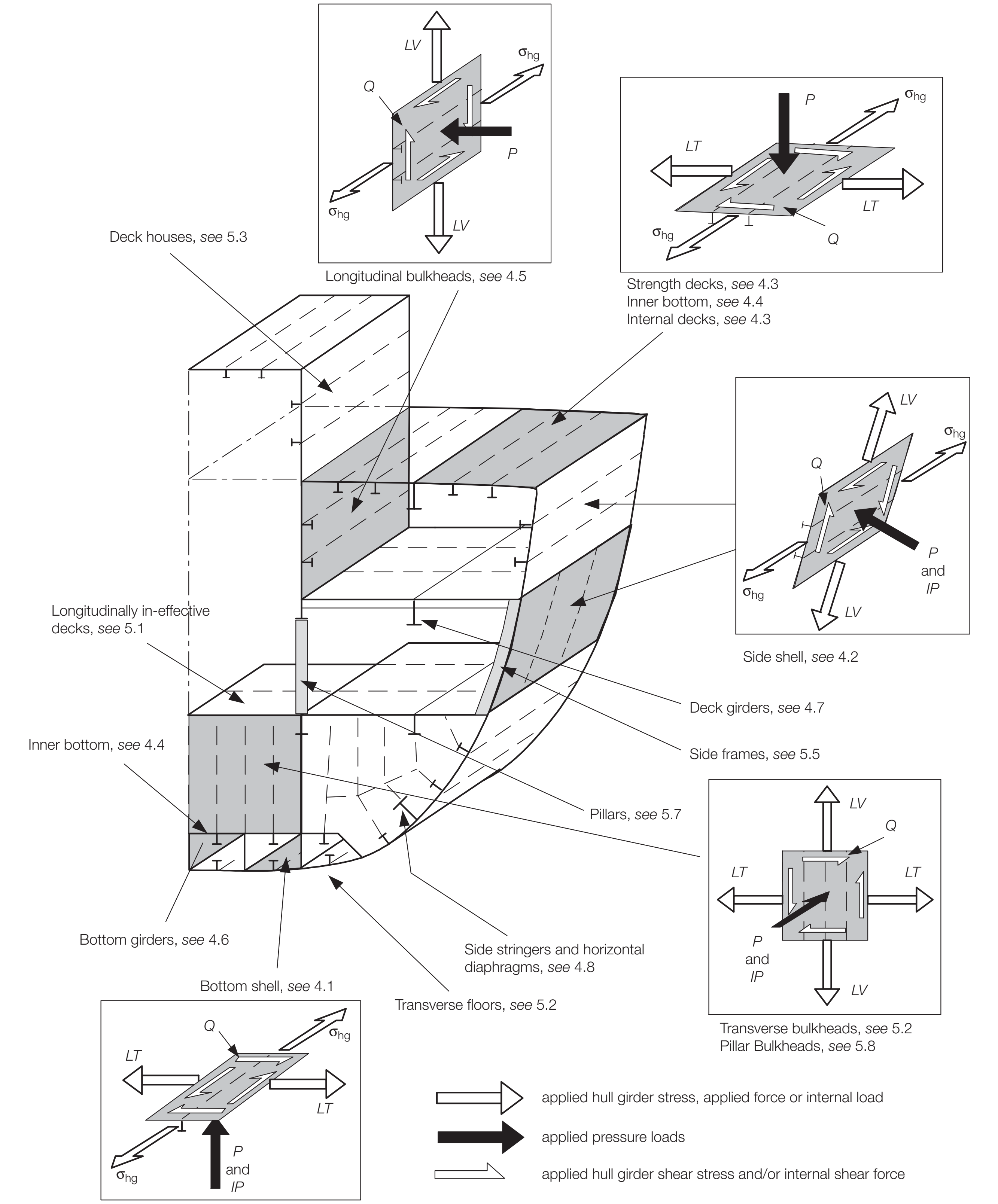


Fig. 2.1.1 Loads and stresses to be applied to the structure

1.4.2 Throughout this chapter, recommended values of effectiveness, ε, are given for each structural component. These effectiveness values specify the proportion of a particular load carried by a structural component as opposed to other supporting structure, see the text for more details. These efficiency values may be derived by direct calculation, similar ship analysis or other suitable techniques. The methods used and values derived are to be agreed with LR.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter to describe the loads applied to or reacted by the structure and local dimensional characteristics, e.g. breadths and spans, is based on the following format:

A_{Suffix}

where

The letter A is the load type or dimension letter and is one of the following:

Load types

- P denotes an applied normal pressure load, i.e. normal to the plate
- IP denotes an applied impulse or impact pressure load
- F denotes an applied point load due to gravity and mass inertial effects
- LV denotes an internally generated load acting in the predominantly vertical direction as a consequence of applied forces and pressures, e.g. pillar bulkhead compressive loads
- LT denotes an internally generated load acting in the predominantly transverse direction as a consequence of applied forces and pressures, e.g. transverse deck compressive loads
- QV denotes a shear force due to local load con-siderations acting in the predominantly vertical direction
- QT denotes a shear force due to local load con-siderations acting in the predominantly transverse direction
- σ denotes a direct stress to apply as a consequence of hull girder bending
- τ denotes a direct shear stress to apply as a consequence of hull girder shear forces

Dimensions

- B breadth, in metres, of an area of supported plate or dimension of a structural member. B is always measured in the transverse direction
- S length of an area of supported plating or dimension of a structural member. S is always measured in the longitudinal direction
- H height of an area of supported plating or dimension of a structural member. H is always measured in the vertical direction

Suffix is either of the following:

- Lower case — to denote a local load value which was derived in accordance with Pt 5, Ch 3
- Upper case — to denote a resultant load value that is applied to the structural item under consideration.

2.1.2 The symbols used in this Chapter for loads are given below:

Local load or pressure components:

- P_{h} = shell envelope hydrostatic pressure, *see* Pt 5, Ch 3,3.2
- P_{w} = shell envelope hydrodynamic pressure, *see* Pt 5, Ch 3,3.3
- P_{wd} = pressure on weather deck, *see* Pt 5, Ch 3,3.5
- IP_{bi} = bottom impact pressure, *see* Pt 5, Ch 3,4.2
- IP_{bf} = Bow flare or above waterline impact pressure, *see* Pt 5, Ch 3,4.3
- P_{in} = pressure on internal deck, *see* Pt 5, Ch 3,5.3
- P_{cd} = pressure on cargo deck, *see* Pt 5, Ch 3,5.4
- P_{ra} = pressure on ramps or lifts, *see* Pt 5, Ch 3,6.2
- H_{tk} = pressure height for tank bulkheads, *see* Pt 5, Ch 3,5.6
- H_{da} = pressure height for watertight bulkheads, *see* Pt 5, Ch 3,5.7

Design loads and pressures for structural components:

- P_{BS} = design pressure for bottom structure
- P_{SS} = design pressure for side shell structure
- P_{DK} = design pressure for deck structure
- P_{WD} = design pressure for weather deck
- P_{ID} = design pressure for interior deck
- P_{IB} = design pressure for inner bottom
- P_{LB} = design pressure for longitudinal bulkheads
- P_{FL} = design pressure for bottom floors and transverses
- P_{DH} = design pressure for deckhouse, bulwarks and superstructures plating
- P_{DT} = design pressure for deep tank bulkheads
- P_{WT} = design pressure for watertight bulkheads
- L_{PI} = design load carried by pillars
- L_{PB} = design load carried by pillar bulkheads
- P_{CD} = design pressure to be applied to cargo decks
- F_{CD} = design load due to discreet mass items to be applied to decks
- P_{IMP} = design pressure for decks subject to impulsive loads
- P_{WI} = design pressure for deckhouse and super-structure windows
- QT_{DK} = local shear force for deck plating
- QT_{FL} = local shear force for floors
- QV_{BG} = local shear force for bottom girders

NOTE

[F] denotes a force matrix, i.e. a group of forces which are applicable to the structural item under consideration.

2.1.3 Other symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

T and L_{R} are defined In Pt 3, Ch 1,5.2.

2.1.4 The units for pressures are in kN/m^2 and the units for loads and forces are in kN. Stresses are in N/mm^2. Positive loads and stresses are tensile, negative are compressive.

2.1.5 The design pressure, p, used in scantling formulae in Ch 3,2 is to be taken as the appropriate pressure value defined in this Chapter.

2.1.6 For a direct calculation using finite element (FE) analysis, only loads and pressures with a load type letter of *P*, *IP* or *F* are normally to be applied to the FE structural model. Load type letters σ_{hg} and τ_{hg} may need to be applied as global bending moments and shear forces, i.e. M_D and Q_D, depending on the extent of the FE structural model.

■ *Section 3*
Design load combinations

3.1 General

3.1.1 The local and global loads given in Pt 5, Ch 3 and Ch 4 do not include any allowance for phase relationships between the various loadings. These loads are not all maximum at the same time and consequently it is not correct to apply all loads simultaneously to the structure. The purpose of this section is to define the phase relationships and hence allow typical maximum load combinations to be applied to the structure.

3.1.2 Special load case combinations may be required to reflect specific operational requirements of the vessel, e.g. seastate 6 operation with the stern well dock flooded for amphibious operations. The details of such operational modes together with any service limitations are to be recorded in the design disclosure document and the Operations Manual, Loading Manual or Stability Information Book.

3.1.3 Proposals for deriving the load combinations using direct calculation techniques are to be agreed with LR at the earliest opportunity.

3.2 Design cases for load combinations

3.2.1 The load combinations given in Table 2.3.1 are the minimum to be considered for the assessment of the scantlings. Additional load combination cases may be required to demonstrate that the structure is adequate.

3.2.2 Each set of load combinations may need to be considered for individual loading conditions to account for differences in local loadings, e.g. different tank fillings, payload or other loadings. This may be performed either using:
1. an envelope approach with due consideration of full/empty tanks, etc., or
2. as individual load combination sets, in which case the actual still water bending moment and shear force distributions may be used together with the actual draft, trim and deadweight distribution.

For example it will be necessary to consider two design cases to review the double bottom tanks, i.e. one with the double bottom tank full and one with the double bottom tank empty.

3.2.3 Load combination cases 1 to 4 are based on the premise that the maximum wave bending moment and shear forces are likely to be generated on a wave that has the same length as the ship.

Table 2.3.1 Design load combination factors

Case No	1	2	3	4	5	6
Design factor	Design Sag case Crest at FP Trough at 0,5L_R	Max pitch bow up Crest at 0,75L_R Trough at 0,25L_R	Design Hog case Crest at 0,5L_R Trough at FP	Max pitch bow down Crest at 0,25L_R Trough at 0,75L_R	Roll case	Design factor affects the following loads
w_g (global loads)	–1,0	$\dfrac{+\sin(\pi x/L_R)}{2}$	+1,0	$\dfrac{-\sin(\pi x/L_R)}{2}$	To be specially considered	M_W, M_{WRS}, Q_W and Q_{WRS} *see* 3.3, 3.4
w_p (external pressures loads)	+ cos $(2\pi x/L_R)$	–sin $(2\pi x/L_R)$	+ cos $(2\pi x/L_R)$	+sin $(2\pi x/L_R)$	To be specially considered	P_{SS}, *see* 3.6 LT QT
w_f (inertial loads)	Combined heave and pitch design factor based on w_{fheave} and w_{fpitch}, *see* 3.5					P_{CD}, F_{CD} LV, L_A
w_{fheave} (heave inertial)	+1	0	–1	0	To be specially considered	
w_{fpitch} (pitch inertial)	0	+1	0	–1	To be specially considered	

NOTES
1 The factor w_g is to be applied to the dynamic portion of the load, *see* 3.3 and 3.4.
2 The factor w_p is to be applied to the dynamic portion of the load component, *see* 3.6.
3 The w_f is to be applied to the dynamic portion of the load component, *see* 3.5. The w_{fheave} and w_{fpitch} factors are required to consider the phasing between heave and pitch accelerations.
4 x is the longitudinal location under consideration.
5 Sin and cos are the sine and cosine functions with the angle in radians.

3.2.4 Each load case combination consists of a set of w factors, some of these combination factors are longitudinally position dependant factors, e.g. the w_p term will produce maximum pressure amidships and low pressures at the ends for the Maximum hogging BM case.

3.3 Design global loads – Intact conditions

3.3.1 The design global hull girder vertical bending moment to be associated with the design load combination cases is as follows:

$M_D = M_S + |w_g| M_W$ kNm

where

$|w_g|$ = absolute value of w_g

M_S and M_W are the sagging or hogging values of M_S and M_W at the longitudinal position under consideration. If w_g is positive then the hogging values of M_S and M_W are to be taken, otherwise w_g is negative and the sagging values of M_S and M_W are to be taken.

M_S and M_W are given in Pt 5, Ch 4,2.2 and 3.3.

w_g is given in Table 2.3.1.

3.3.2 The design global hull girder vertical shear force to be associated with the design load combination cases is as follows:

$Q_D = Q_S + |w_g| Q_W$ kN

where

$|w_g|$ = absolute value of w_g

Q_S and Q_W are the sagging or hogging values of Q_S and Q_W at the longitudinal position under consideration. If w_g is positive then the hogging values of Q_S and Q_{WH} are to be taken, otherwise w_g is negative and the sagging values of Q_S and Q_{WS} are to be taken.

Q_S is given in Pt 5, Ch 4,2.3

Q_{WS} and Q_{WH} are given in 3.7

w_g is given in Table 2.3.1.

3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions

3.4.1 The design global hull girder vertical bending moments to be associated with the design load combination cases for residual strength assessment or damaged conditions is to be taken as follows:

$M_D = M_{SRS} + |w_g| M_{WRS}$ kNm

where

$|w_g|$ = absolute value of w_g

M_{SRS} and M_{WRS} are the sagging or hogging values of M_{SRS} and M_{WRS} at the longitudinal position under consideration. If w_g is positive then the hogging values of M_{SRS} and M_{WRS} are to be taken, otherwise w_g is negative and the sagging values of M_{SRS} and M_{WRS} are to be taken.

M_{SRS} and M_{WRS} are given in Pt 5, Ch 4,5.6

w_g is given in Table 2.3.1.

3.4.2 The design global hull girder vertical shear force to be associated with the design load combination cases for residual strength assessment or damaged conditions is to be taken as follows:

$Q_D = Q_{SRS} + |w_g| Q_{WRS}$ kN

where

$|w_g|$ = absolute value of w_g

Q_{SRS} and Q_{WRS} are the sagging or hogging values of Q_{SRS} and Q_{WRS} at the longitudinal position under consideration. If w_g is positive then the hogging values of Q_{SRS} and $Q_{WRS,H}$ are to be taken, otherwise w_g is negative and the sagging values of Q_{SRS} and $Q_{WRS,S}$ are to be taken.

Q_{SRS} is given in Pt 5, Ch 4,5.6 and 5.4

w_g is given in Table 2.3.1

$Q_{WRS,S}$ and $Q_{WRS,H}$ are given in 3.7.2.

3.5 Inertial force load combination factor, w_f

3.5.1 The inertial force load combination factor, w_f, to be associated with the design load combination cases is as follows:

$w_f = (1 + a_z)$

where

$a_z = w_{fheave}\, a_{heave} + w_{fpitch}\, a_{pitch}$

w_{fheave} and w_{fpitch} are to be taken for the appropriate loading condition, *see* Table 2.3.1

a_{heave} and a_{pitch} are defined in Pt 5, Ch 3, Table 3.2.1

3.6 External shell pressures

3.6.1 The side shell pressure, P_{SS}, to be applied to all external plating is to be derived as follows:

$P_{SS} = P_h + w_p P_w$ kN/m^2

but

$P_{SS} \geq 0$

w_p is defined in Table 2.3.1

P_h and P_w are defined in Pt 5, Ch 3,3.2 and 3.3.

3.6.2 The weather deck pressure, P_{WD}, to be applied to all external plating is to be derived as follows:

$P_{WD} = P_h + w_p P_{wd}$ kN/m^2

but

$P_{WD} \geq 0$

w_p is defined in Table 2.3.1

P_{wd} is defined in Pt 5, Ch 3,3.5.

3.7 Vertical wave shear forces

3.7.1 The wave shear force curves associated with the hogging and sagging bending moments are required by the total load approach are to be taken as follows:

Q_{WH} = shear force distribution to give the hogging bending moment
= $3K_b\,M_o/L_R$ kN

where

K_b is to be taken as follows:

K_b = 0 at aft end of L_R
= $+0{,}836F_{fH}$ between $0{,}2L_R$ and $0{,}3L_R$
= $+0{,}65F_{fH}$ between $0{,}4L_R$ and $0{,}5L_R$
= $-0{,}65F_{fH}$ between $0{,}5L_R$ and $0{,}6L_R$
= $-0{,}91F_{fH}$ between $0{,}7L_R$ and $0{,}85L_R$
= 0 at forward end of L_R

Q_{WS} = shear force distribution to give the sagging bending moment
= $3K_b\,M_o/L_R$ kN

where

K_b is to be taken as follows:

K_b = 0 at aft end of L_R
= $+0{,}836F_{fS}$ between $0{,}15L_R$ and $0{,}3L_R$
= $+0{,}65F_{fS}$ between $0{,}4L_R$ and $0{,}5L_R$
= $+0{,}65F_{fS}$ between $0{,}5L_R$ and $0{,}6L_R$
= $-0{,}91F_{fS}$ between $0{,}7L_R$ and $0{,}85L_R$
= 0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

M_o, F_{fH} and F_{fS} are given in Pt 5, Ch 4,3.3.

3.7.2 The wave shear force associated with the residual strength assessment load cases or damaged load cases is to be taken as follows:

$Q_{WRS,H}$ = shear force distribution to give the hogging bending moment
= $K_{fRS}\,Q_{WH}$

where

Q_{WH} is taken as in 3.7.1
K_{fRS} is given in Pt 5, Ch 4,5.2

$Q_{WRS,S}$ = shear force distribution to give the sagging bending moment
= $K_{fRS}\,Q_{WS}$

where

Q_{WS} is taken as in 3.7.1.

■ *Section 4* Design load systems for longitudinally effective components

4.1 Bottom shell structures (BS)

4.1.1 The design load values calculated here are to be used to determine the scantlings of bottom shell plating and stiffeners between the keel and the turn of bilge, *see* Fig. 2.4.1.

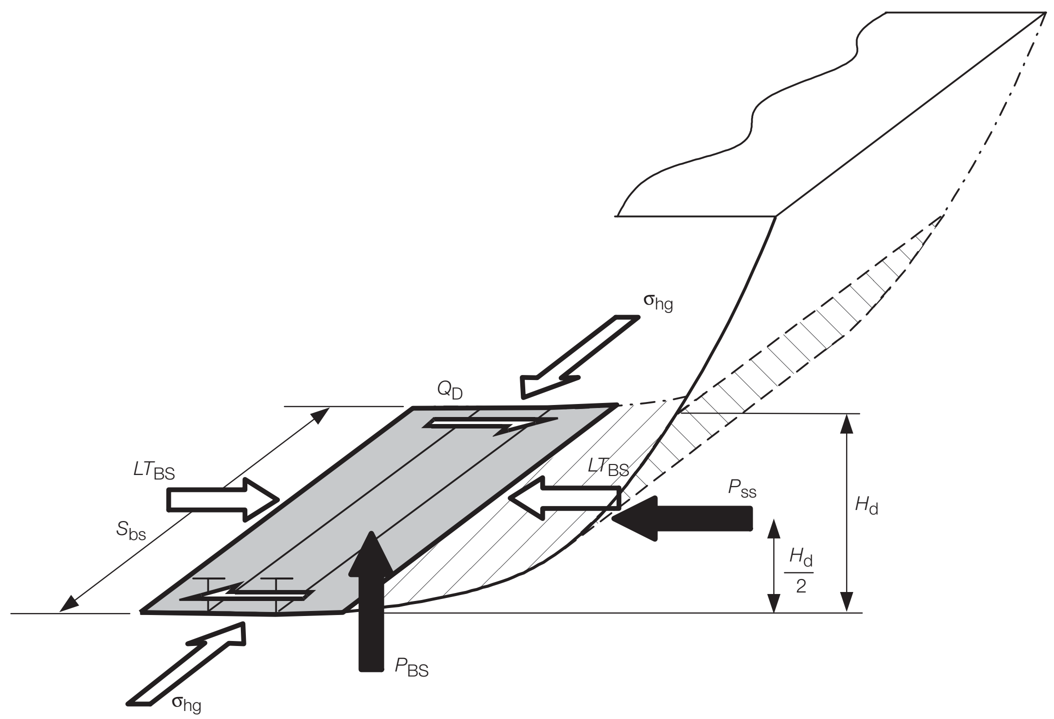


Fig. 2.4.1 Loads to be applied to bottom shell structure

4.1.2 The design normal pressure, P_{BS}, for the bottom shell plating and stiffeners is to be taken as:

$P_{BS} = P_{SS}$ kN/m^2

where

P_{SS} is defined in 3.6.1.

4.1.3 The design impulse pressure, IP_{BS}, for the bottom shell plating and stiffeners is to be taken as

IP_{bi} kN/m^2 (bottom impact)

where

IP_{bi} is defined in 2.1.2.

4.1.4 The design global vertical bending moment for bottom shell plating and longitudinals is to be taken as M_D, as defined in 3.3 or 3.4.

4.1.5 The design transverse load, LT_{BS}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{BS} = -\varepsilon_{BS} P_{SS} H_d S_{bs}$ kN

where

H_d = half the vertical distance from the keel to the first effective full breadth deck above the inner bottom, or above the keel, in m. If no effective full breadth decks exist, then H_d is to be taken to the strength deck. H_d is illustrated in Fig. 2.4.2

S_{bs} = length of the bottom shell plating between major transverse bulkheads, in metres

ε_{BS} = effectiveness of the bottom shell plating, i.e. the relative proportion of the load carried by the bottom shell as opposed to other structure such as the inner bottom, floors and bulkheads
= 0,5 for full breadth double bottom structures
= 1,0 for single bottom structures or partial breadth double bottom structures

P_{SS} is to be taken at a height $H_d/2$ above the keel. P_{SS} is defined in 3.6.1.

4.1.6 The design global shear force, Q_D, may be ignored for the bottom plating.

4.1.7 The design loads for bottom structure primary members are given in 4.6, bottom longitudinal girders, and 5.4, transverse floors.

4.2 Side shell structures (SS)

4.2.1 The design pressures calculated here are to be used to determine the scantlings of side shell plating and stiffeners from the turn of bilge up to the weather deck, *see* Fig. 2.4.3.

4.2.2 For the side shell structure the design normal pressure, P_{SS}, is to be taken as defined in 3.6.1.

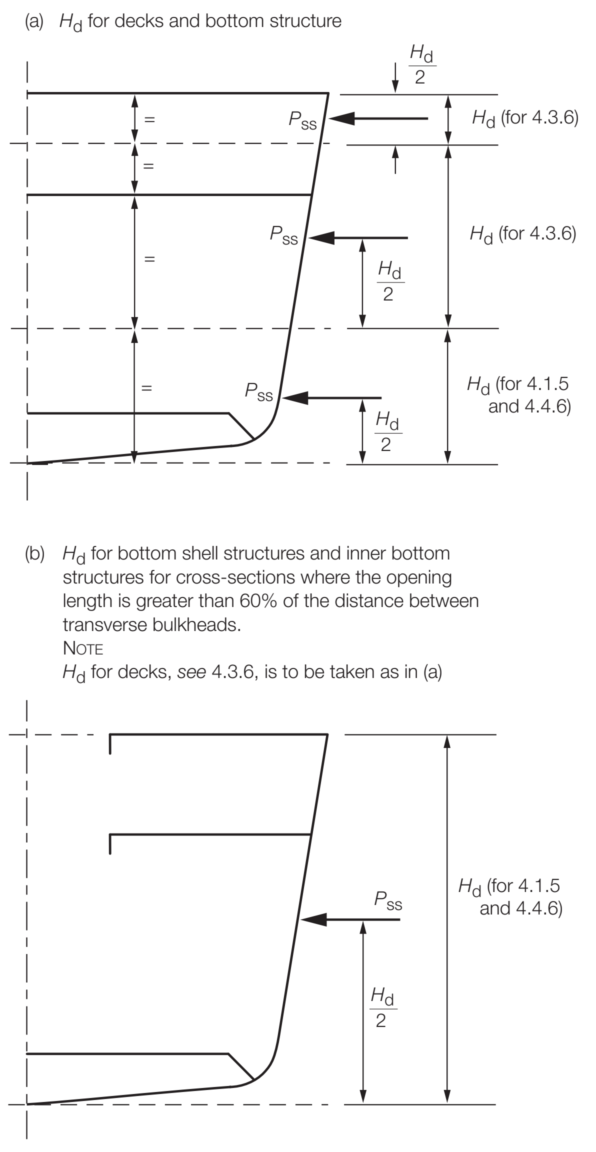


Fig. 2.4.2
Design parameter H_d for transverse load

4.2.3 The design impulse pressure, IP_{SS}, for the side shell plating and stiffeners is to be taken as follows:

1. up to the design waterline
   $IP_{SS} = IP_{bi}$ kN/m^2 (bottom impact)
2. above the design waterline
   $IP_{SS} = IP_{bf}$ kN/m^2 (bow flare impact)

where

IP_{bi} and IP_{bf} are defined in 2.1.2.

4.2.4 The design global vertical bending moment is to be taken as M_D, as defined in 3.3 or 3.4.

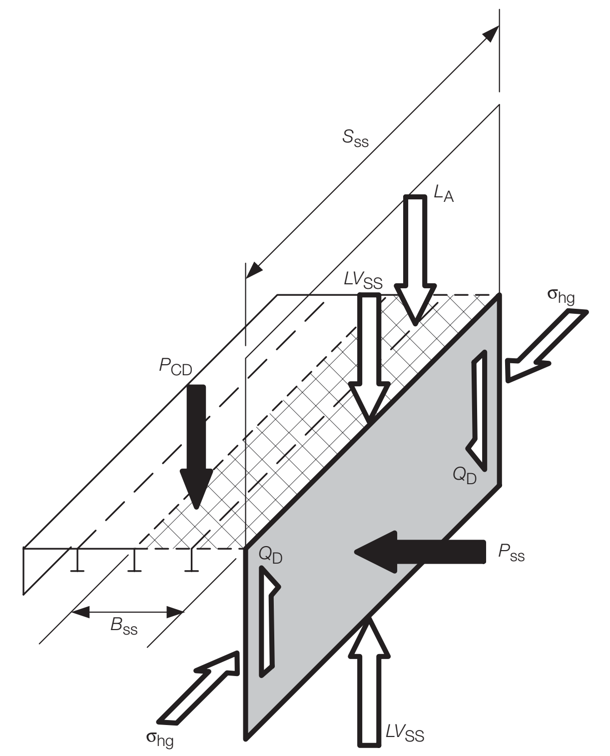


Fig. 2.4.3
Loads to be applied to side shell structure

4.2.5 The design vertical load, LV_{SS}, supported by the side shell plating and stiffeners is to be taken as:

LV_{SS} = $-\varepsilon_{SS}$ (S_{ss} B_{ss} P_{CD} + L_A + [F_{CD}]) kN

where

ε_{SS} = effectiveness of the side shell plating, i.e. the relative proportion of the load carried by the side shell as opposed to the bounding major transverse bulkheads
= 0,5

P_{CD} = basic inertial deck design pressure, as appropriate, plus any other local loadings directly above the side shell, in kN/m^2, *see* 5.1.2

[F_{CD}] = inertial load or loads, in kN, from items of equipment, etc on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

L_A = appropriate load, in kN, from pillar(s), bulkheads and side shell structure above the supported deck, assumed zero if there are none over. L_A may be taken as LV_{BP} for the supported bulkhead. LV_{PB} is given in 5.8

S_{ss}, B_{ss} are the effective deck area supported by the side shell and are to taken as follows, *see* Fig. 2.4.3

B_{ss} = mean breadth of the supported deck plating, i.e. half the transverse distance from the side shell to longitudinal bulkheads, or effectively supported longitudinal girders, in metres

S_{ss} = length of the side shell between major transverse bulkheads, in metres.

4.2.6 The design global shear force is to be taken as Q_D, as defined in 3.3 or 3.4.

4.2.7 The design loads for side shell primary members are given in 4.8 for longitudinal stringers and in 5.5 for side frames and web frames.

4.3 Strength deck and internal deck structures (DK)

4.3.1 The design normal pressure, P_{DK}, for the deck plating and stiffeners is to be taken as the greater of the following, provided that the load component is applicable:

1. P_{WD} (weather deck pressure), *see* 3.6.2.
2. P_{ID} (interior deck pressure), *see* 5.1.3.
3. P_{CD} (cargo deck pressure), *see* 5.1.2.
4. P_{tk} (deep tank boundary, where appropriate).

4.3.2 For loading conditions which represent damaged situations and for decks that form part of the watertight subdivision, the design normal pressure, P_{DK}, is to be taken as follows if this is greater than 4.3.1:

P_{da} (damage head).

4.3.3 The design load matrix, [F_{DK}], in kN for the deck plating and stiffeners is to be taken as the combination of the following, as appropriate:

[F_{CD}] *see* 5.1.5 (equipment or other deck loads)

L_A pillar loads from above, if not transferred to pillars below, *see* 4.2.5

These loads are to be applied in addition to the design pressures above.

4.3.4 Normally, the design impulse pressure, IP_{DK}, for the deck plating and stiffeners may be ignored. However the design impulse pressure will need to be considered for decks designed to withstand helicopter or aircraft landing operations, cargo handling at sea or similar.

4.3.5 The design global vertical bending moment is to be taken as M_D, as defined in 3.3 or 3.4.

4.3.6 The design transverse load, LT_{DK}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows, *see also* 4.3.8:

LT_{DK} = $-\varepsilon_{DK}$ P_{SS} H_d S_{dk} kN

where

H_d = half the vertical distance from the first full breadth deck below the deck under consideration to the first full breadth deck above this deck, or to the strength deck if there are no decks above, in metres

S_{dk} = length of the side shell plating between major transverse bulkheads, in m, *see* Fig. 2.4.4

ε_{DK} = effectiveness of the deck, i.e. the relative proportion of the load carried by the deck as opposed to other structure such as bulkheads
= 0,8

P_{SS} is to be taken at the mid height of the H_d depth, P_{SS} is defined in 3.6.1

H_d is illustrated in Fig. 2.4.2.

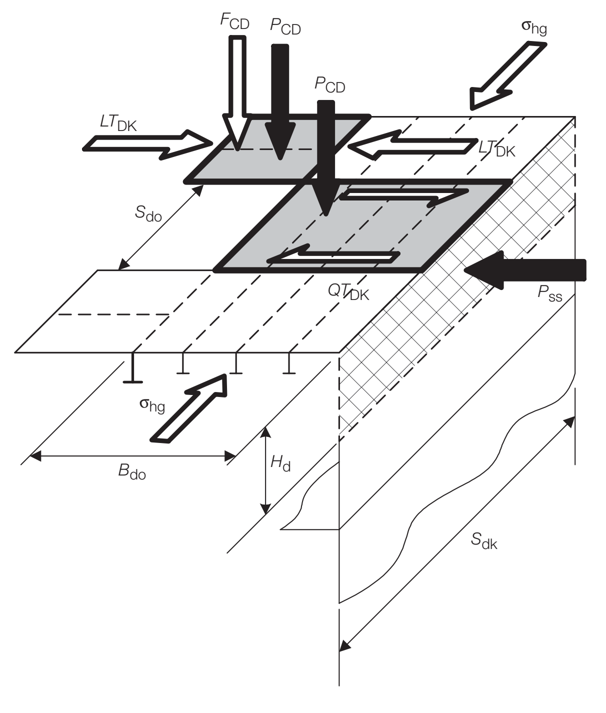


Fig. 2.4.4
Design loads for the deck structure

4.3.7 Normally, the design global shear force may be ignored for the deck plating. However if the structural arrangement is such that significant shear load is carried by the deck, then it should be considered. In this case the design global shear force is to be taken as Q_D, as defined in 3.3 or 3.4.

4.3.8 If the deck is not continuous across the full breadth, due the presence of large openings, then LT_{DK} may be taken as zero over the opening breadth. In this case it may be necessary to consider the local shear force in the deck plating due to hydrostatic and hydrodynamic loading on the longitudinal span of the deck. This shear force acts in the transverse direction and is to be taken as:

$QT_{DK} = P_{SS}\, H_d\, S_{do}/2$ kN

where

S_{do} = length of the deck plating between major transverse bulkheads or the length of the deck opening, whichever is lesser, in metres

P_{SS} and H_d are defined in 4.3.6

The shear area of the deck plate supporting this shear load is to be based on the breadth of the deck edge strip, B_{do}.

4.3.9 The transverse load, LT_{DK}, in way of the full breadth decks at the ends of the deck opening is to be increased by the ratio:

$S_d/(S_d - S_{do})$

And the efficiency of the deck, ε_{DK} *see* 4.3.6, may be reduced provided that the transverse bulkheads are capable of carrying more of the transverse loading.

4.3.10 The design loads for deck primary members are given in 4.7 for deck girders and in 5.6 for deck beams.

4.4 Inner bottom structures (IB)

4.4.1 For all loading conditions, the design normal pressure, P_{IB}, for the inner bottom plating and stiffeners is to be taken as the greater of:

1. P_{ID} (interior deck pressure), *see* 5.1.3.
2. P_{CD} (cargo deck pressure), *see* 5.1.2.
3. P_{tk} (deep tank pressure, where appropriate).

4.4.2 For loading conditions which represent damaged situations, the design normal pressure, P_{IB}, for the inner bottom plating and stiffeners is to be taken as the greater of the following. If this is greater than 4.4.1:

1. P_{da} (damage head).
2. P_{SS} (pressure on shell plating, where appropriate).

4.4.3 The design load matrix, $[F_{IB}]$, in kN for the inner bottom plating and stiffeners is to be taken as:

$[F_{CD}]$ (equipment or other deck loads), *see* 5.1.5.

4.4.4 The design impulse pressure for the inner bottom plating and stiffeners may be ignored.

4.4.5 The design global vertical bending moment for the inner bottom plating and stiffeners is to be taken as M_D, as defined in 3.3 or 3.4.

4.4.6 The design transverse load, LT_{IB}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{IB} = -\varepsilon_{IB}\, P_{SS}\, H_d\, S_{ib}$ kN

where

H_d = half the vertical distance from the keel to the first full breadth deck above the inner bottom, in metres

S_{ib} = span of the bottom shell plating between major transverse bulkheads, in metres, *see* Fig. 2.4.5

ε_{IB} = effectiveness of the inner bottom, i.e. the relative proportion of the load carried by the inner bottom as opposed to other structure such as the bottom shell, floors and bulkheads

= 0,5 normally

P_{SS} is to be taken at a height of $H_d/2$ above the keel, P_{SS} is defined in 3.6

H_d is illustrated in Fig. 2.4.2.

4.4.7 The design global shear force, Q_D, may be ignored for the inner bottom plating.

4.4.8 The design loads for inner bottom structure primary members are given in 4.6 for bottom longitudinal girders and in 5.4 for transverse floors.

4.5 Longitudinal bulkhead structures (LB)

4.5.1 The design normal pressure for longitudinal bulkhead plating with longitudinal stiffeners is to be taken as the same for both the plating and stiffeners. The design normal pressure, P_{LB}, is to be taken as P_{BHP} as given in 5.2.1.

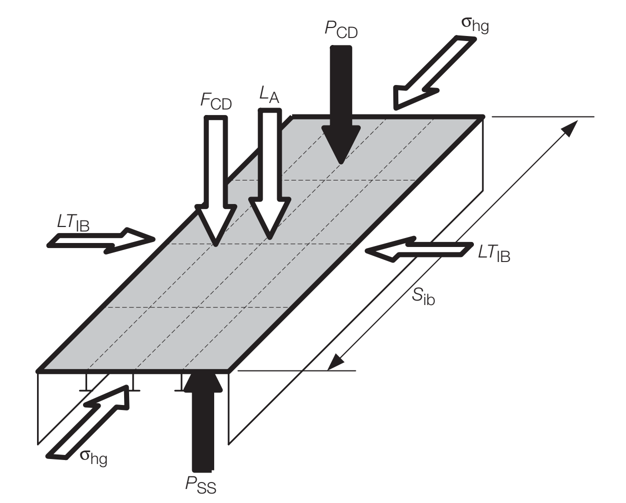


Fig 2.4.5
Loads to be applied to inner bottom plating

4.5.2 The design normal pressure for longitudinal bulkhead plating with vertical stiffeners is to be considered separately for the plating and the vertical stiffeners. The design normal pressure for the plating, P_{LB}, is to be taken as P_{BHP} as given in 5.2.1. The design normal pressure for the stiffener, P_{LBS}, is to be taken as P_{BHS} as given in 5.2.1.

4.5.3 The design impulse pressure, IP_{LB}, for the longitudinal bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar.

4.5.4 The design global vertical bending moment for longitudinal bulkhead plating and stiffeners is to be taken as M_D as defined in 3.3 or 3.4.

4.5.5 The design vertical load, LV_{LB}, at each intersecting deck level is to derived as follows:

$LV_{LB} = -(S_{lb}\, B_{lb}\, P_{CD} + L_A + [F_{CD}])$ kN

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2, *see* 5.1.2

$[F_{CD}]$ = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

L_A = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over, *see also* 4.2.5

S_{lb} B_{lb} is the effective deck area supported by the longitudinal bulkhead and can be taken as follows, *see* Fig. 2.4.6:

B_{lb} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres

S_{lb} = span or length of the longitudinal bulkhead between major transverse bulkheads, in metres.

4.5.6 The design global shear force for longitudinal bulkhead plating is to be taken as Q_D, as defined in 3.3 or 3.4.

4.5.7 If the longitudinal bulkhead is not continuous over the full depth of the ship then it will be necessary to consider the local shear force in the longitudinal bulkhead plating as the vertical load must be transferred into the supporting structure, such as transverse bulkheads. This shear force acts in the vertical direction and is to be taken as:

$QV_{LB} = LV_{LB}/2$

The shear area of the longitudinal bulkhead plate supporting this shear load is to be based on the depth of the longitudinal bulkhead between decks.

4.5.8 The design loads for longitudinal bulkhead primary members are given in 4.8 for longitudinal stringers and in 5.5 for side frames and web frames.

4.6 Bottom longitudinal girders (BG)

4.6.1 This sub section covers double bottom and single bottom girders. Fig. 2.4.7 illustrates the design loads.

4.6.2 The design normal pressure, P_{BG}, for girder web plating is to be taken as the greater of:

1. P_{tk} kN/m^2 (Deep Tank, if applicable), *see* 5.1.4.
2. P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations), *see* 5.1.4.
3. 5,0 (minimum value for no direct loading).

4.6.3 The design impulse pressure, IP_{BG}, for the bottom girder web plating may be ignored, unless these members are subjected to sloshing loads or similar.

4.6.4 The design global vertical bending moment for bottom girder plating and stiffeners is to be taken as M_D, as defined in 3.3 or 3.4.

4.6.5 The design vertical load, LV_{BG}, acting on the web plating of bottom girders is to be based on the supported loads. Typically these include downwards local inertial pressures, P_{CD}, inertial forces, $[F_{CD}]$, and pillar bulkhead loads above, L_A, all acting on the plating of the inner bottom or the bottom girder flange and the upwards buoyancy loads on the bottom shell plating, P_{BS}. The design vertical load is to be taken as:

$LV_{BG} = -\varepsilon_{BG}\,(B_{bg}\, S_{bg}\,(P_{CD} - P_{BS}) + [F_{CD}] + L_A)$ kN

where

ε_{BG} = effectiveness of the bottom girders, i.e. the relative proportion of the load carried by the bottom girders as opposed to other structure such as the transverse floors
= 0,5

B_{bg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see* Note 2

S_{bg} = span or length of the longitudinal girder between transverse bulkheads, in metres

L_A = load, in kN, from pillar(s) above, assumed zero if there are none over, *see* 4.2.5

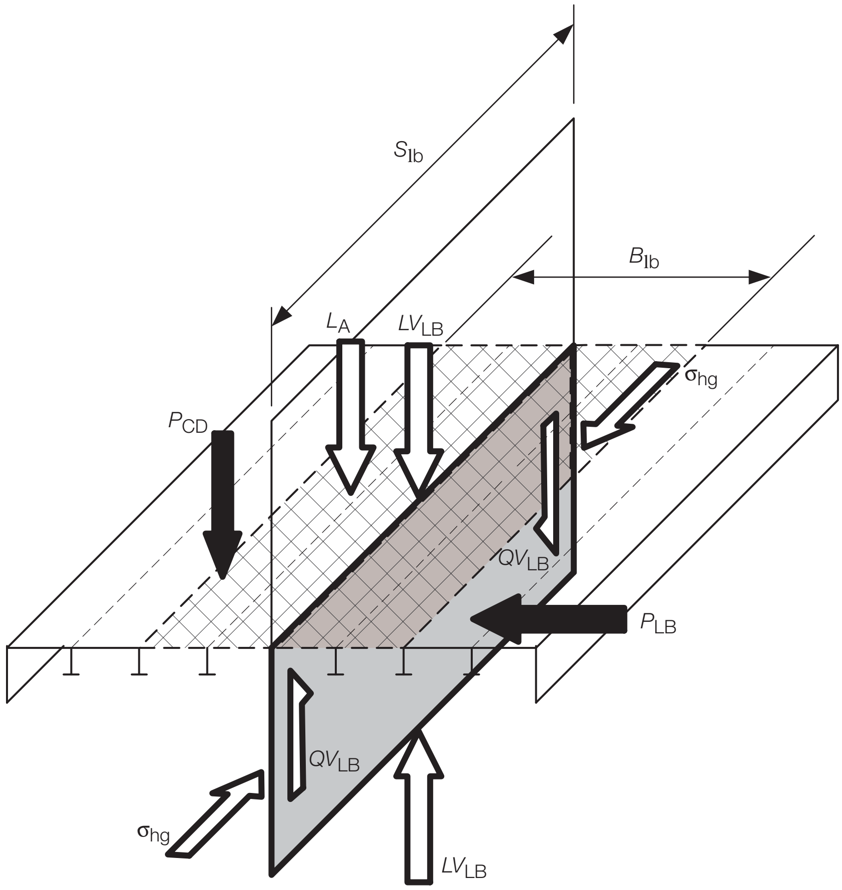


Fig. 2.4.6 Loads to be applied to longitudinal bulkhead plating

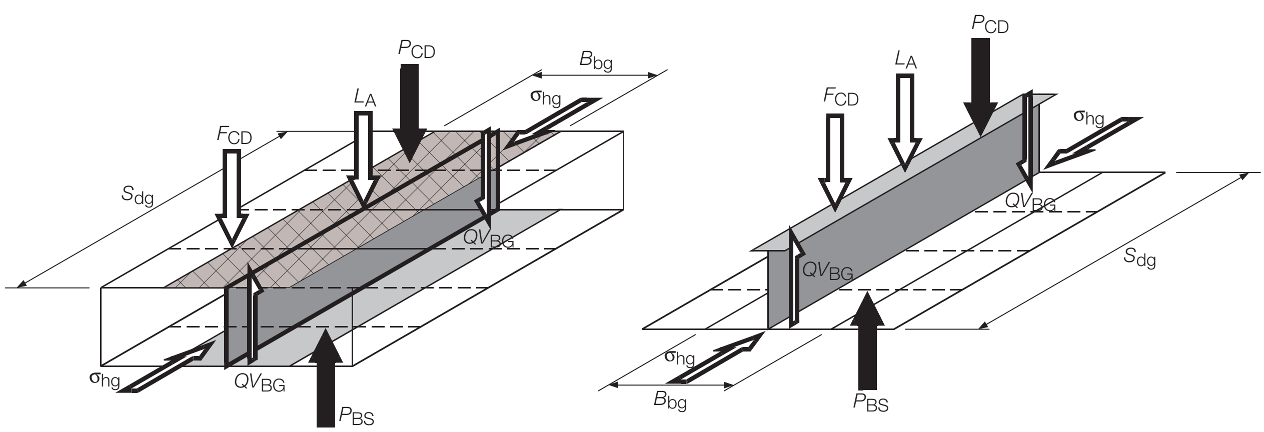


Fig. 2.4.7 Loads to be applied to bottom girders

F_{CD} = inertial load or loads, in kN, from items of equipment, etc on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

P_{BS} is defined in 4.1.2

P_{CD} is defined in 5.1.2.

NOTES

1. For single bottom girders P_{CD} is likely to be zero. In this situation B_{bg} = span or length of the longitudinal girder between transverse bulkheads. P_{CD} should be taken as the distributed machinery load, if it is not included in $[F_{CD}]$.
2. Where the girder is part of a longitudinally stiffened bottom structure with closely spaced floors, the mean spacing B_{bg} may be taken as the spacing of the longitudinal stiffeners. For grillage or transversely stiffened systems then the spacing is to be taken as stated.

4.6.6 The design shear force for the bottom girder web plating is to include local and global components.

1. The design global shear force is to be taken as Q_D, as defined in 3.3 or 3.4. If the girder depth is reasonably small then Q_D may be ignored.
2. The local shear force component, QV_{BG}, is due to the difference between the buoyancy and the inertial forces. It acts in the vertical direction and is to be taken as:

$$QV_{BG} = \varepsilon_{BG} (B_{bg} S_{bg} (P_{CD} - P_{BS}) + [F_{CD}] + L_A)/2$$

where

B_{bg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see* Note 2.

4.6.7 The design bending load for bottom girder primary member is to be taken as:

$$\varepsilon_{BG} (B_{bg} S_{bg} (P_{CD} - P_{BS}) + [F_{CD}] + L_A) \quad \text{kN}$$

4.6.8 The membrane loads acting on the bottom shell plating are defined in 4.1. The membrane loads acting on the inner bottom plating are defined in 4.4. These loads are required to assess the bottom girder beam in addition to the local bending loads.

4.7 Deck girders (DG)

4.7.1 The design normal pressure, P_{DG}, for deck girder web plating may be ignored.

4.7.2 The design impulse pressure, IP_{DG}, for deck girder web plating may be ignored, unless these members are subjected to sloshing loads or similar.

4.7.3 The design global vertical bending moment for deck girders is to be taken as M_D, as defined in 3.3 or 3.4.

4.7.4 The design vertical load for deck girder webs may be ignored.

4.7.5 The design shear force for the deck girder web plating is to include local and global components.

1. The design global shear force is to be taken as Q_D, as defined in 3.3 or 3.4. If the girder depth is reasonably small then Q_D may be ignored.
2. The local shear force component, QV_{DG}, is due to the difference between the buoyancy and the inertial forces. It acts in the vertical direction and is to be taken as:

$$QV_{DG} = \varepsilon_{BG} (B_{dg} S_{dg} P_{CD} + [F_{CD}] + L_A)/2 \quad \text{kN}$$

where

ε_{BG} = effectiveness of the deck girders, i.e. the relative proportion of the load carried by the deck girders as opposed to other structure such as the deck beams
= 0,5

B_{dg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see* Fig. 2.4.8

S_{dg} = span or length of the longitudinal girder between transverse bulkheads, in metres

L_A = load, in kN, from pillar(s) above, assumed zero if there are none over

F_{CD} = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5.

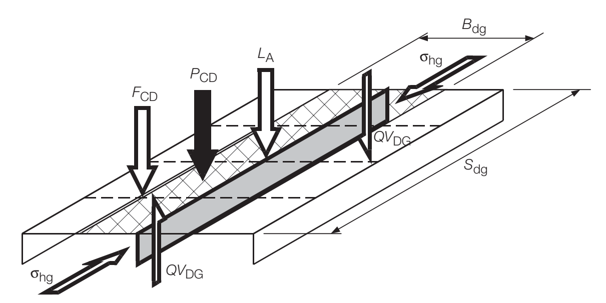


Fig. 2.4.8 Loads to be applied to deck girders

4.7.6 The membrane loads acting on the deck plating are defined in 4.3.

4.7.7 The design bending load for the deck girder primary member is to be taken as:

$$\varepsilon_{BG} (B_{dg} S_{dg} P_{CD} + [F_{CD}] + L_A) \quad \text{kN.}$$

4.8 Longitudinal stringers (ST)

4.8.1 This sub section covers stringers supporting side shell plating, horizontal girders on longitudinal bulkheads and also covers horizontal diaphragms fitted between a double skin. The design loads are illustrated in Fig. 2.4.9.

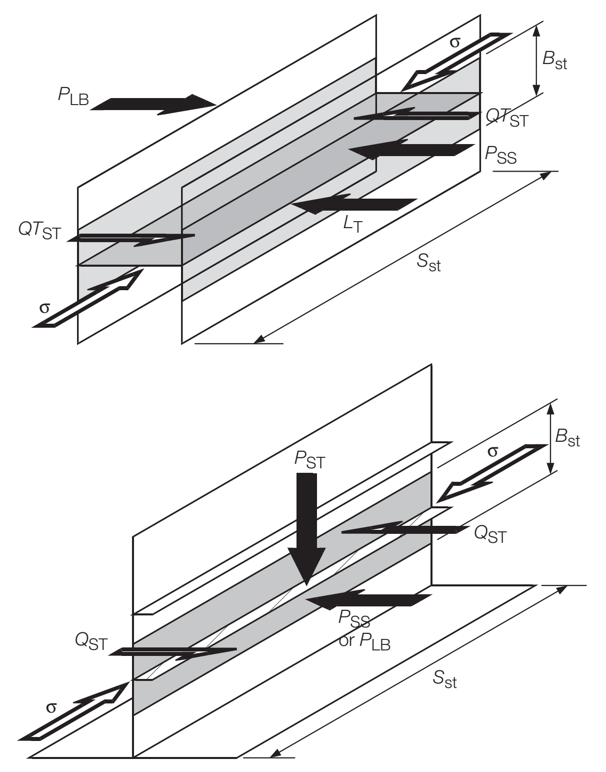


Fig. 2.4.9 Design loads for longitudinal stringers

4.8.2 The design normal pressure, P_{ST}, for the web plating of stringer may be ignored unless the stringer forms part of a tank boundary or watertight subdivision, i.e. a watertight horizontal diaphram. In this case the design pressure is to be taken as the greater of

1. P_{tk} kN/m^2 (Deep Tank, if applicable), *see* 5.1.4.
2. P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations), *see* 5.1.4.
3. 5,0 (minimum value for no direct loading).

4.8.3 The design impulse pressure, IP_{ST}, for the web plating of stringer may be ignored, unless these members are subjected to sloshing loads or similar.

4.8.4 The design global vertical bending moment for longitudinal stringers is to be taken as M_D, as defined in 3.3 or 3.4.

4.8.5 The design transverse load, LT_{ST}, acting on the web plating of horizontal diaphragms is to be based on the pressure loads acting on the plating of the inner skin or longitudinal bulkhead P_{LB} (outwards) and the side shell P_{SS} (inwards). The design transverse load, LT_{ST}, is to be taken as the lesser of:

1. $-\varepsilon_{ST}\, B_{st}\, S_{st}\, P_{SS}$ kN
2. $-\varepsilon_{ST}\, B_{st}\, S_{st}\, P_{LB}$ kN

where

ε_{ST} = effectiveness of the horizontal diaphragms, i.e. the relative proportion of the load carried by the horizontal diaphragms as opposed to other structure such as the transverse web or normal frames
= 0,5

H_{st} = mean spacing, in m, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar

S_{st} = length of the stringer (or horizontal girder) between transverse bulkheads, in m, *see* Fig. 2.4.9

P_{SS} is to be taken as the side shell pressure at the height of the stringer, *see* 3.6.1. P_{SS} is to be ignored for horizontal girders attached to longitudinal bulkheads.

P_{LB} is to be taken as the longitudinal bulkhead normal pressure at the height of the horizontal girder, *see* 4.5.1. This is only required for longitudinal bulkheads that form part of a deep tank or watertight boundary.

NOTE

Where the horizontal diaphram is part of a longitudinally stiffened structure with regular transverse webs, the mean spacing H_{st} may be based on the longitudinal spacing. For grillage or transversely stiffened systems then the spacing is to be taken as originally stated.

4.8.6 The design transverse load, LT_{ST}, for stringers and horizontal girders may be ignored.

4.8.7 The design shear force, QT_{ST}, in the stringer web due to hydrostatic, hydrodynamic or tank loading acts in the transverse direction and is to be taken as the greater of:

1. $\varepsilon_{ST}\, H_{st}\, S_{st}\, P_{SS}/2$
2. $\varepsilon_{ST}\, H_{st}\, S_{st}\, P_{LB}/2$

where

H_{st} = mean spacing, in m, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar.

4.8.8 The design bending load for the deck girder primary member is to be taken as:

$\varepsilon_{ST}\, H_{st}\, S_{st}\, (P_{SS} - P_{LB})$

where

H_{st} = mean spacing, in metres, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar.

4.8.9 The membrane loads acting on the side shell and longitudinal bulkhead plating are defined in 4.2 and 4.5, these loads are required to assess the longitudinal stringer beam in addition to the local bending loads.

■ *Section 5*

Design load systems for structural components or longitudinally ineffective material

5.1 Deck structures (DK)

5.1.1 The design pressure, P_{WD}, for weather deck structure is given in 3.6.2.

5.1.2 For weather decks and interior decks subjected to cargo loads or other pressure loading then the following design pressure is to be used for the plating and stiffeners if it is greater than that given in 5.1.1:

$P_{CD} = w_f W_{cd}$ kN/m^2

where

W_{cd} is the static pressure exerted be the cargo, payload, stores or equipment on the deck as specified by the designer in kN/m^2, *see* 2.1.2 and *see also* Pt 5, Ch 3,5.4.1.

w_f is given in 3.5.1.

5.1.3 The design pressure, P_{ID}, for interior deck plating and stiffeners is given by:

$P_{ID} = w_f W_{in}$ kN/m^2

P_{ID} is not to be taken less than 2,5 kN/m^2

W_{in} is defined in 2.1.2.

5.1.4 For weather or internal decks which form part of a deep tank or watertight boundary then the pressure loading is to be taken as the greater of the following if this is greater than the above:

$P_{tk} = 9{,}81\rho\,(H_{tk} - z)$ kN/m^2 (Deep Tank, if applicable)

$P_{da} = 10(H_{da} - z)$ kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations)

where

ρ = specific density of liquid in the tank, to be taken as not less than 1,025

z = distance above the baseline of the mid depth of the deck plating

H_{tk} and H_{da} are defined in 2.1.2.

5.1.5 The cargo deck design force matrix, $[F_{CD}]$, for plating and stiffeners is to be taken as below for all mass items which act over the deck area considered

$[F_{CD}] = w_f\,[W_{ma}]$

W_{ma} is the weight of each item on the deck as specified by the designer in kN. *See also* Pt 5, Ch 3,5.4.2.

5.1.6 If the deck is required to be immersed during its operation, e.g. an internal dock area, then the deck is to be designed using the side shell pressure loads, P_{SS}, *see* 3.6.1.

5.2 Transverse watertight and deep tank bulkheads (BH)

5.2.1 The design normal pressure for bulkhead plating, P_{BHP}, and stiffeners, P_{BHS}, is to be taken as the pressure values P_{bhp} and P_{bhs} respectively given in Pt 5, Ch 3,5.8.

5.2.2 The design impulse pressure, IP_{BH}, for the bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar.

5.2.3 The design transverse load, LT_{BH}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{BH} = -\varepsilon_{BH} P_{SS}\, H_{bh}\, S_{bh}$ kN

where

H_{bh} = half the vertical distance from the deck below the bulkhead under consideration to the deck above, in metres, *see* Fig. 2.5.1 and Fig. 2.5.2

S_{bh} = half the longitudinal distance between adjacent transverse bulkheads, in metres

ε_{BH} = effectiveness of the bulkhead, i.e. the relative proportion of the load carried by the bulkhead as opposed to other structure such as decks

ε_{BH} may be taken as 0,5

alternatively ε_{BH} may be taken as

$\varepsilon_{BH} = H_{bh}/(2S_{bh})$ for $H_{bh} < S_{bh}$

and $= 1 - S_{bh}/(2H_{bh})$ for $H_{bh} > S_{bh}$

P_{SS} is to be taken at the mid height of the H_{bh} depth, P_{SS} is defined in 3.6.1.

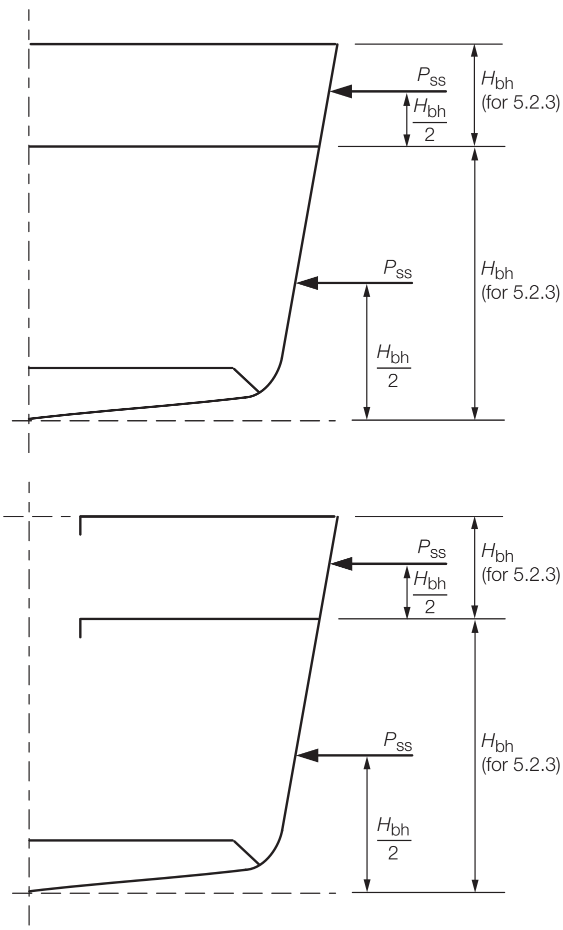


Fig. 2.5.1
Design parameter H_{bh} for transverse loads

5.2.4 The design vertical load, LV_{BH}, supported by the transverse bulkheads is to be based on the pressure loads acting on the plating of the supported deck over, P_{CD}, the local inertial forces, $[F_{CD}]$, and the bulkhead loads above, L_A. The design vertical load is to be taken as

$LV_{BH} = -(B_{bh}\, S_{bh}\, P_{CD} + [F_{CD}] + L_A)$ kN

where

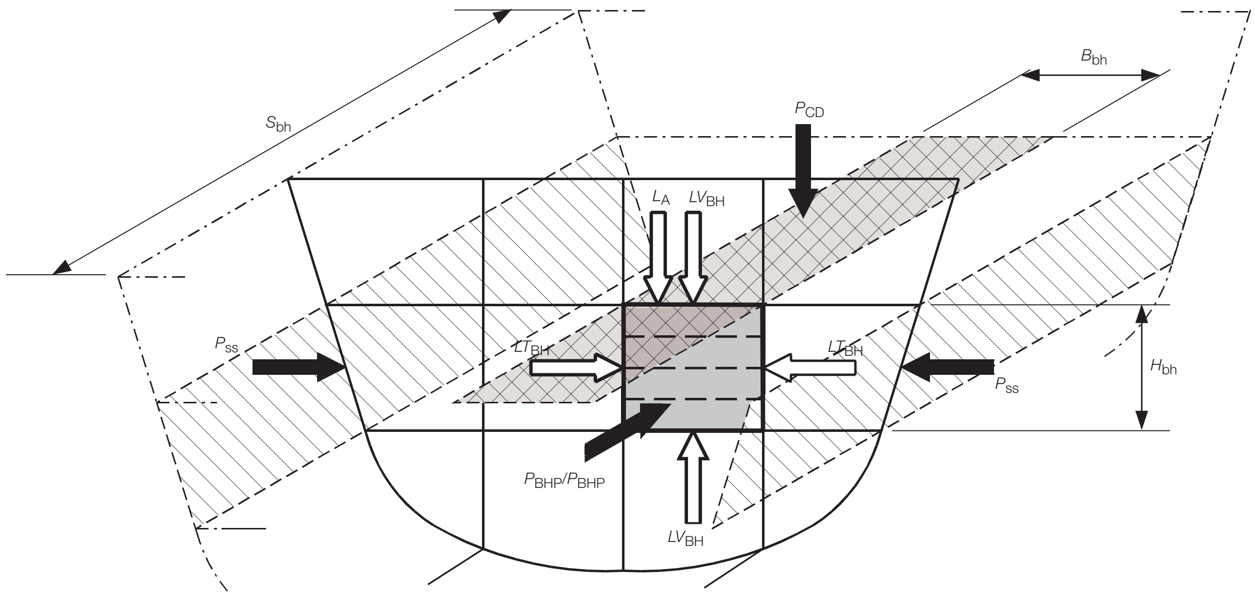


Fig. 2.5.2 Design loads for bulkheads

B_{bh} = breadth of the deck supported by the bulkhead, in metres

L_A = load, in kN, the bulkhead above, assumed zero if there are none over, *see* 4.2.5

F_{CD} = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

P_{CD} is defined in 5.1.2.

5.2.5 Normally, the design shear force, QV_{BH}, may be ignored for bulkhead plating. However if the structural arrangement or load paths are such that significant shear load is carried by the bulkhead, then it should be considered, e.g. when the bulkhead is not continued down to the bottom shell. In this case the design shear force, acting in the vertical direction, is to be taken as

$QV_{BH} = LV_{BH} /2$ kN

where

LV_{BH} is given in 5.2.4.

5.3 Deckhouses, bulwarks and superstructures (DH)

5.3.1 The design normal pressure, P_{DH}, for the plating and stiffeners of deckhouses, bulwarks and the first tier and above of superstructures is given by:

$P_{DH} = P_{dh}$ kN/m^2

5.3.2 For the side plating and longitudinal bulkheads of deckhouses and superstructures, the design vertical load, LV_{DH}, at each intersecting deck level is to be taken as follows:

$LV_{DH} = -\varepsilon_{DH} (S_{dh} B_{dh} P_{CD} + L_A + [F_{CD}])$ kN

where

P_{CD} = basic deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2

$[F_{CD}]$ = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

L_A = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over, *see* 4.2.5

ε_{DH} = effectiveness of the side plating or longitudinal bulkhead, i.e. the relative proportion of the load carried by this plating as opposed to other structure such as the transverse bulkheads
= 0,5

$S_{dh} B_{dh}$ is the effective deck area supported by the deckhouse side plating or longitudinal bulkheads and can be taken as follows:

B_{dh} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres

S_{dh} = span or length of the side plating or longitudinal bulkhead between major deckhouse transverse bulkheads, in metres.

5.3.3 For transverse bulkheads of deckhouses and superstructures, the design vertical load, LV_{DH}, at each intersecting deck level is to be taken as follows:

$LV_{DH} = -\varepsilon_{DH} (S_{dh} B_{dh} P_{CD} + L_A + [F_{CD}])$ kN

where

ε_{DH} = efficiency of the transverse bulkheads i.e. the relative proportion of the load carried by the transverse bulkheads as opposed to other structure such as the side plating
= 0,5

$S_{dh} B_{dh}$ is the effective deck area supported by the transverse bulkhead and can be taken as follows:

S_{dh} = mean spacing of transverse bulkheads, in metres

B_{dh} = breadth of the transverse bulkhead, in metres.

5.3.4 For decks of deckhouses, the design transverse load, LT_{DH}, at each deck level may normally be ignored.

5.3.5 If the superstructure or deckhouse is longitudinally effective then the design global vertical bending moment and shear force are to be taken as M_D and Q_D respectively, *see* 3.3 or 3.4 for the design of the side plating and longitudinal bulkheads of deckhouse structures.

5.4 Transverse floors (FL)

5.4.1 The design normal pressure, P_{FL}, for the web plating of floors of double bottom or single bottom structures is to be taken as the greater of the following:

1. P_{tk} kN/m^2 (Deep tank floor).
2. P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations).
3. 5 kN/m^2 (minimum value).

where

P_{da} and P_{tk} are defined in 5.1.4.

5.4.2 The design impulse pressure, IP_{FL}, for the web plating of floors may be ignored, unless these members are subjected to sloshing loads or similar.

5.4.3 The design vertical load, LV_{FL}, for the floors is to be based on the pressure loads acting on the plating of the inner bottom P_{CD} (downwards) and the bottom shell P_{BS} (upwards), the local inertial forces $[F_{CD}]$ and pillar bulkhead loads above L_A. The design vertical load, LV_{FL}, is to be taken as:

$LV_{FL} = -\varepsilon_{FLV} (B_{fl}\, S_{fl}\, (P_{CD} - P_{BS}) + [F_{CD}] + L_A)$ kN

where

ε_{FLV} = effectiveness of the floors in the vertical direction, i.e. the relative proportion of the load carried by the transverse floors as opposed to bottom girders, etc.
= 1,0 for the floor halfway between transverse bulkheads

S_{fl} = mean spacing of transverse floors, in metres, *see* Fig. 2.5.3

B_{fl} = breadth of the transverse floor between longitudinal bulkheads or side shell(s), in metres. NOTE B_{fl} may be full breadth

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over, *see* 4.2.5

F_{CD} = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

P_{BS} is defined in 4.1.2

P_{CD} is defined in 5.1.2.

NOTES

- For single bottom floors P_{CD} is likely to be zero.
- It may be necessary to take account of the impact loading on the bottom plating in the derivation of LV_{FL} and QV_{FL}.

5.4.4 The design transverse load, LT_{FL}, for the floor plating due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{FL} = -\varepsilon_{FLT}\, P_{SS}\, H_d\, S_{fl}$ kN

where

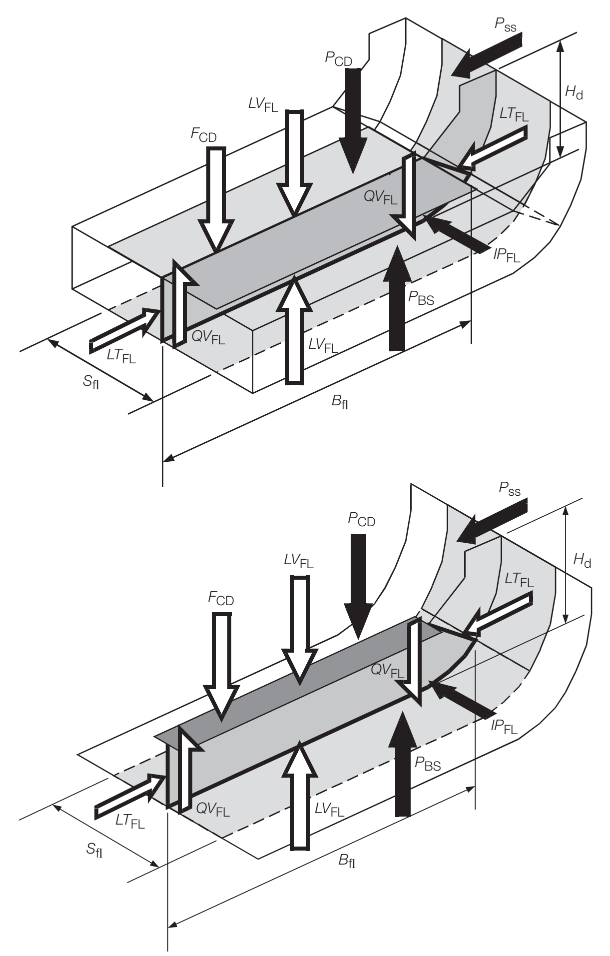


Fig. 2.5.3 Loads to be applied to transverse floors

ε_{FLT} = effectiveness of the floors in the transverse direction, i.e. the relative proportion of the load carried by the floor plating as opposed to other bottom structure
= $0{,}3f_b$ for double bottom structures
= $0{,}5f_b$ for single bottom structures

f_b = 2,0 for bottom structures where transverse elastic buckling of outer bottom plating is likely
= 3,0 for bottom structures where transverse elastic buckling of inner and outer bottom plating is likely
= 1,0 otherwise

P_{SS} and H_d are to be taken as the values defined for the bottom structure in 4.1.5.

5.4.5 The design shear force, QV_{FL}, for the floor web plating due to local loading acts in the vertical direction and is to be taken as:

$QV_{FL} = \varepsilon_{FLV} (B_{fl}\, S_{fl}\, (P_{CD} - P_{BS}) + [F_{CD}] + L_A)/2$ kN

5.4.6 The design bending load for bottom floor primary member is to be taken as LV_{FL}.

5.4.7 The membrane loads acting on the bottom shell plating are defined in 4.1. The membrane loads acting on the inner bottom plating are defined in 4.4. These membrane loads are required to assess the transverse floors in addition to the local bending loads.

5.5 Side frames and web frames (SF)

5.5.1 This sub section covers side frames, web frames and frames supporting longitudinal bulkheads.

5.5.2 The design normal pressure, P_{SF}, for the web plating of side frames may be ignored.

5.5.3 The design impulse pressure, IP_{SF}, for the web plating of side frames may be ignored, unless these members are subjected to sloshing loads or similar.

5.5.4 The design vertical load, LV_{SF}, for the side frames, including the attached plating is to be based on the pressure loads acting on the plating of the supported deck over, P_{CD}, the local inertial forces, $[F_{CD}]$, and side frame loads above, L_A. The design vertical load is to be taken as:

$LV_{SF} = -(B_{fr}\, S_{fr}\, P_{CD} + [F_{CD}] + L_A)$ kN

where

S_{fr} = mean spacing of side frames, in metres, *see* Fig. 2.5.4

B_{fr} = breadth of the deck supported by the side frame, in metres

L_A = load, in kN, the side frame above, assumed zero if there are none over, *see* 4.2.5

F_{CD} = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

P_{CD} is defined in 5.1.2.

5.5.5 The design transverse load, LT_{SF}, may be ignored for the side frames.

5.5.6 The design shear force, QT_{SF}, for the side frame web plating due to local loading acts in the transverse direction and is to be taken as:

$QT_{SF} = H_{fr}\, S_{fr}\, P_{SS}/2$ kN

where

H_{fr} = length of the side frame between adjacent decks, *see* Fig. 2.5.4

P_{SS} is to be taken at the mid height of the side frame, P_{SS} is defined in 3.6.1

NOTE

It may be necessary to take account of the impact loading on the side frame plating in the derivation of QT_{SF}.

5.5.7 The design bending load for side frame or web frame primary member is to be taken as:

$H_{fr}\, S_{fr}\, P_{SS}$ for frames attached to side shell

$H_{fr}\, S_{fr}\, P_{LB}$ for frames attached to longitudinal bulkheads.

5.5.8 The membrane loads acting on the side shell or longitudinal bulkhead plating are defined in 4.2 or 4.5. These membrane loads are required to assess the frames in addition to the local bending loads.

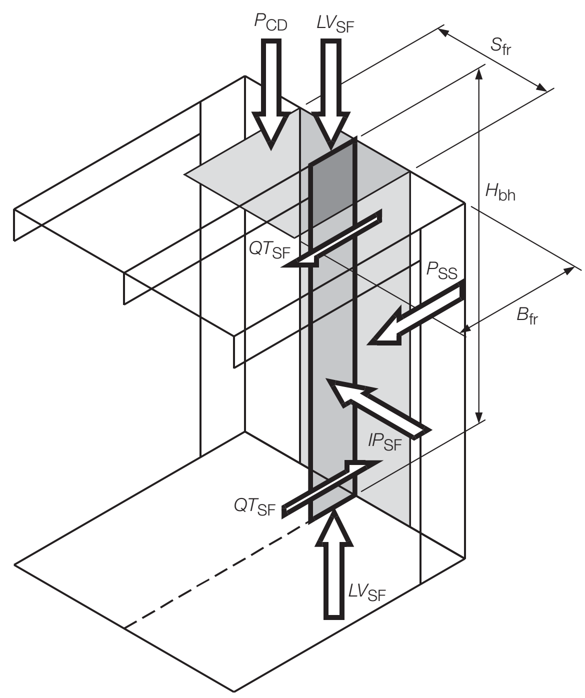


Fig. 2.5.4
Loads to be applied to side frames

5.6 Deck beams (BM)

5.6.1 This sub-Section covers deck beams and deep transverse beams supporting deck structure.

5.6.2 The design normal pressure, P_{BM}, for the web plating of deck beams may be ignored.

5.6.3 The design impulse pressure, IP_{BM}, for the web plating of deck beams may be ignored, unless these members are subjected to sloshing loads or similar.

5.6.4 The design vertical load, LV_{BM}, for the deck beam may be ignored.

5.6.5 The design transverse load, LT_{BM}, for the deck beam due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{BM} = -P_{SS}\, H_d\, S_{bm}$ kN

where

P_{SS} and H_d are to be taken as the values defined for the deck plating in 4.3.6.

5.6.6 The design shear force, QV_{BM}, for the deck beam web plating is to be based on the pressure loads acting on the plating of the deck P_{CD} (downwards), the local inertial forces $[F_{CD}]$ and pillar bulkhead loads above L_A. The shear force acts in the vertical direction and is to be taken as:

$$QV_{BM} = (B_{bm}\,S_{bm}\,P_{CD} + [F_{CD}] + L_A)/2 \text{ kN}$$

where

S_{bm} = mean spacing of deck beams, in metres, *see* Fig. 2.5.5

B_{bm} = span of the deck beams between longitudinal bulkheads, pillars or side shell, in metres

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over, *see* 4.2.5

F_{CD} = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

P_{CD} is defined in 5.1.2.

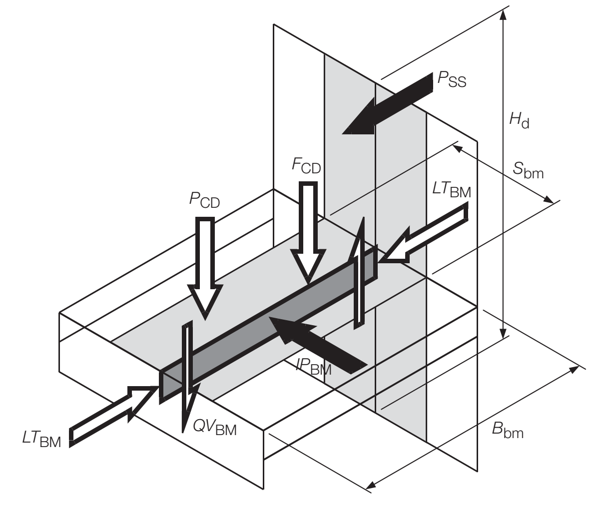


Fig. 2.5.5 Loads to be applied to deck beams

5.6.7 The design bending load for deck beam primary member is to be taken as:

$$(B_{bm}\,S_{bm}\,P_{CD} + [F_{CD}] + L_A) \text{ kN}$$

5.6.8 The membrane loads acting on the deck plating are defined in 4.3. These membrane loads are required to assess the frames in addition to the local bending loads.

5.7 Pillars (PI)

5.7.1 The design load, LV_{PI}, supported by the pillar is to be taken as:

$$LV_{PI} = -(S_{pi}\,B_{pi}\,P_{CD} + L_A + [F_{CD}]) \text{ kN}$$

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2. Where the pillar supports a deck area over which the design pressure varies, then the summation of the these loads is to be used, *see* 5.1.2

$[F_{CD}]$ = appropriate portion of the inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

$B_{pi}\,S_{pi}$ is the effective deck area supported by the pillar bulkhead

B_{pi} = mean spacing of transverses supported by pillars or transverse bulkheads, in metres, *see* Fig. 2.5.6

S_{pi} = mean spacing of girders supported by the pillars, longitudinal bulkheads or side shell, in metres

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over may be taken as LV_{PI} for the supported pillar or LV_{PB} for the supported bulkhead, *see* 5.8

LV_{PI} is not to be taken less than 5 kN.

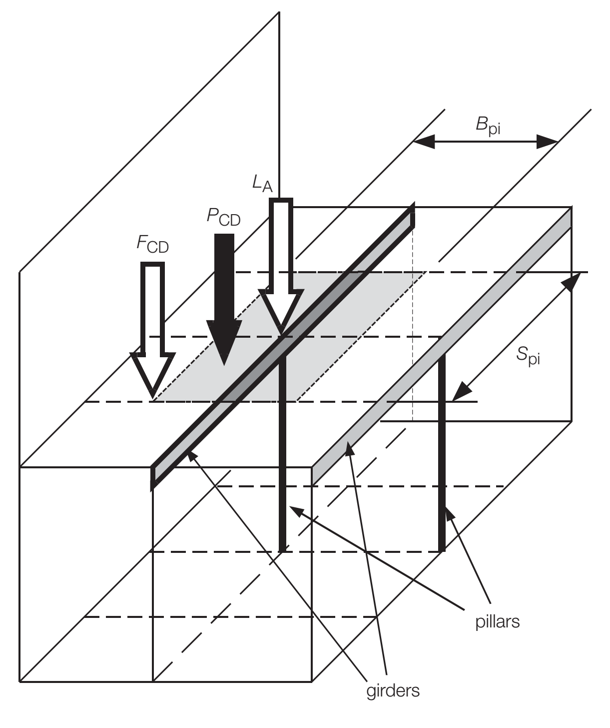


Fig. 2.5.6 Loads supported by a pillar

5.7.2 When any of the conditions below are satisfied then the pillar load should be derived using direct calculation methods:

- where the structural arrangement is complex;
- where it is considered that the load in the pillar will not be accurately represented by the above formulae, e.g. pillars supporting decks in way of the ends of a long superstructure block;
- where the pillar is not supported underneath by the double bottom or substantial structural members.

5.8 Pillar bulkheads (PB)

5.8.1 The vertical in-plane compressive load supported by a pillar bulkhead is to be taken as:

LV_{PB} = – (S_{pb} B_{pb} P_{CD} + L_A + [F_{CD}]) kN

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2, *see* 5.1.2

[F_{CD}] = inertial load or loads, in kN, from items of equipment, etc., on the supported deck, assumed zero if there are none over. F_{CD} is defined in 5.1.5

L_A = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there are none over, may be taken as LV_{PI} for the supported pillar or LV_{PB} for the supported bulkhead

S_{pb}, B_{pb} is the effective deck area supported by the pillar bulkhead and can be taken as follows:

(a) For longitudinal pillar bulkheads, *see* Fig. 2.5.7:

B_{pb} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres

S_{pb} = length of the pillar bulkhead between major transverse bulkheads or effectively supported transverse web frames or similar, in metres

(b) For transverse pillar bulkheads:

S_{pb} = mean spacing of transverse bulkheads or effectively supported transverse web frames or similar, in metres

B_{pb} = breadth of the pillar bulkhead between major longitudinal bulkheads or the side shell, in metres.

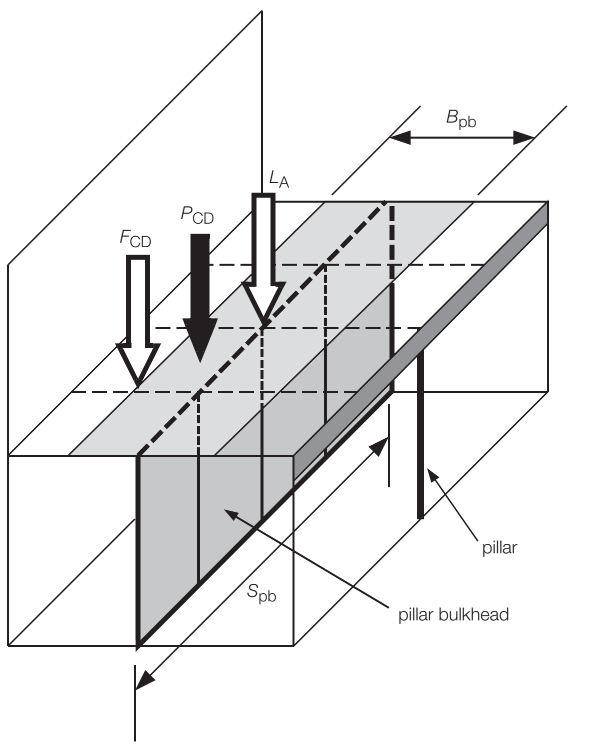


Fig. 2.5.7 Loads supported by a pillar bulkhead

5.8.2 When any of the conditions below are satisfied then the pillar bulkhead load should be derived using direct calculation methods:

- where the structural arrangement is complex;
- where it is considered that the load in the pillar bulkhead will not be accurately represented by the above formulae, e.g. pillar bulkheads supporting decks in way of the ends of a long superstructure block;
- where the pillar bulkhead is not supported underneath by the double bottom or substantial structural members.

■ *Section 1* Introduction

1.1 General

1.1.1 The Total Load Assessment, **TLA**, procedure is an optional procedure that is applied on a voluntary basis when an Owner or designer who seeks to increase confidence levels in the structural integrity of a ship. The **TLA** procedure is illustrated in Fig. 3.1.1.

1.1.2 The **TLA** procedure is based on the following concepts:

1. Derive the total design loads acting on each structural member.
2. Derive the structural resistance of each structural member.
3. Derive the load utilisation factors.
4. Ensure the load utilisation factors are less than the required design factors.

1.1.3 This Chapter gives the simplified stress analysis methods to be used for the **TLA** procedure. Direct calculations or alternative proven methods of analysis which are more rigorous will be accepted.

1.1.4 The design loads for the **TLA** procedure are given in Chapter 2, Total Design Loads.

1.1.5 The structural design factors are given in Section 4 and utilise the design criteria in Pt 6, Ch 5.

1.1.6 The simplified stress analysis techniques predict the total stresses acting in the structure as a consequence of the total loads. These techniques cover the assessment of stresses in the following:

- Primary structure.
- Primary/secondary plating systems.
- Grillage plating systems.

1.1.7 The resulting stresses are then checked against a set of design factors, which include stress, deflection and buckling requirements.

1.1.8 The **TLA** procedure is in addition to the normal Rule structural design approval requirements specified within Pt 6, Ch 3.

1.2 Structural design

1.2.1 The **TLA** procedure only forms part of the structural design process, **TLA** covers the structural design of the ship in the sea environment only. There are many other structural requirements as a consequence of other loads and good structural design practices that need to be incorporated. These include:

- bow flare impact and bottom slamming loads;
- ice requirements;
- design requirements to cover other strength issues, for example helicopter or vehicle decks;
- military requirements such as fragmentation protection.
- local impact loadings due to tugs, docks;
- supporting structure for machinery, cranes and lifting devices; and
- corrosion margins.

1.2.2 The structural design should clearly exhibit good structural continuity and smooth transition of scantlings between adjacent plating areas. In general, the **TLA** derived maximum scantlings for each structural member at any section within $0,3L_R$ to $0,7L_R$ are to be maintained over the central region.

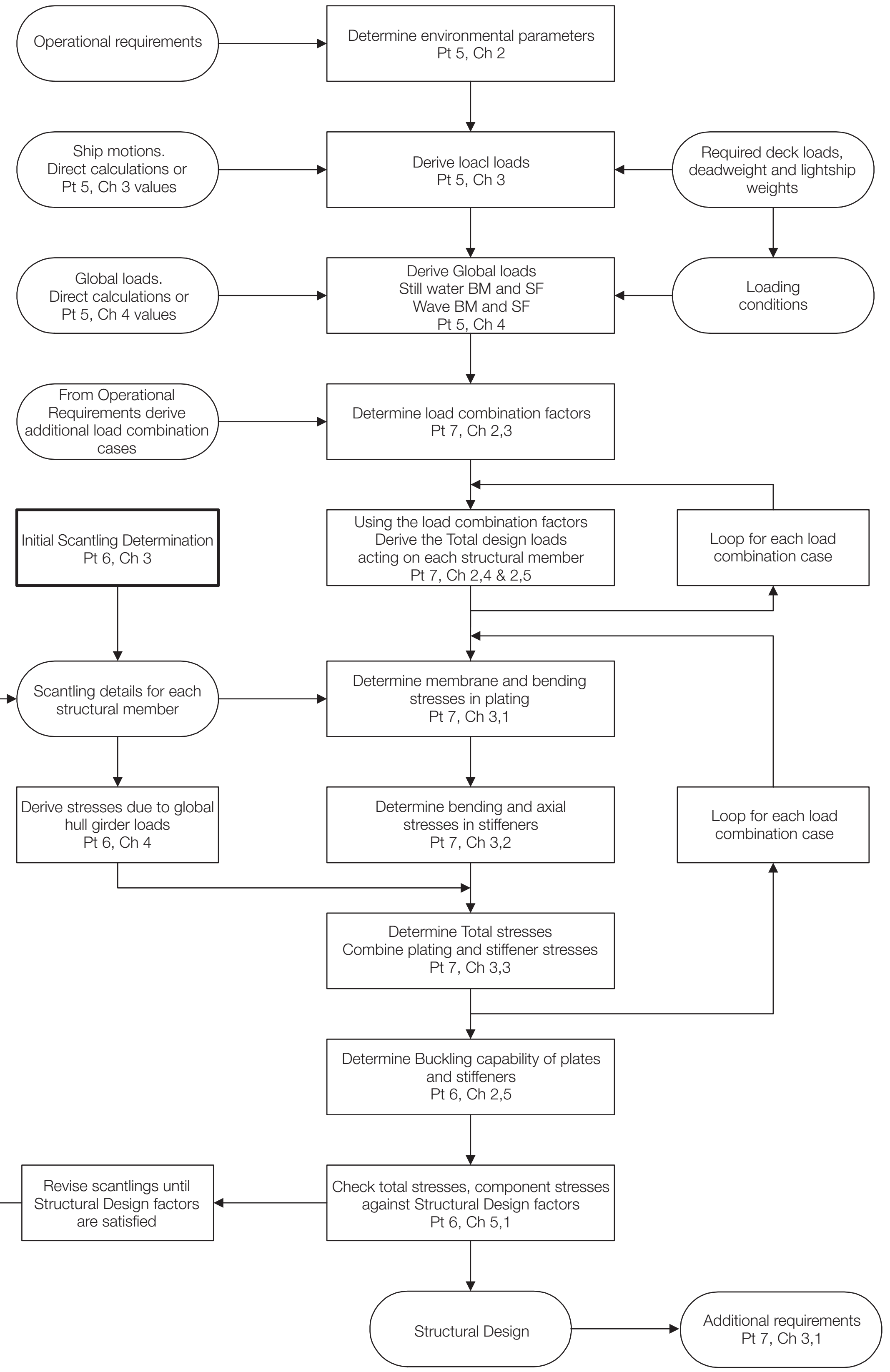


Fig. 3.1.1 Overview of the Total Load Assessment, TLA Procedure

■ *Section 2*
Structural resistance

2.1 Assessment of stresses in structural components

2.1.1 The equations and methods given below are to be used to derive the stresses acting within plating and within stiffeners and beams.

2.1.2 These equations are valid for plating and beams subjected to lateral, or normal, pressure or point loads, i.e. local design considerations.

2.1.3 The stresses in plating and beams subjected to hull girder loads are to be derived in accordance with the methods given in Pt 6, Ch 4.

2.2 Stresses in plating

2.2.1 The loads acting on a plate panel and its dimensions are illustrated in Fig. 3.2.1.

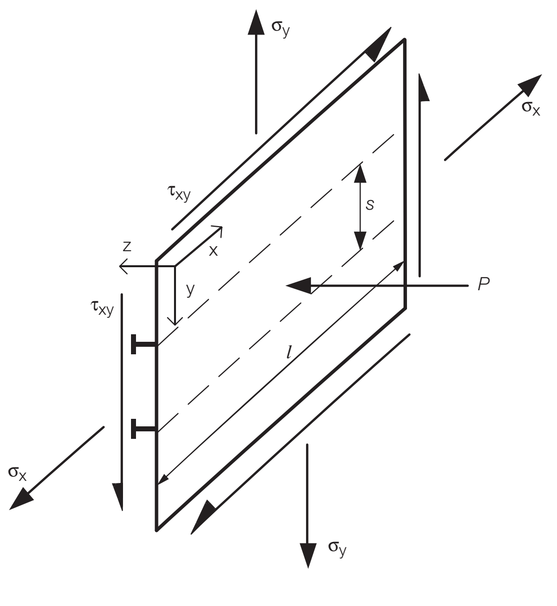


Fig. 3.2.1
Membrane stress system for plating

2.2.2 The bending stress in a plate panel between stiffeners due to a uniform lateral pressure is to be calculated as follows:

$$\sigma_b = p\left(\frac{22{,}4s\,\gamma\,\beta}{1000t_p}\right)\ \text{N/mm}^2$$

where

p = lateral pressure, in kN/m^2
t_p = thickness of plating, in mm
s = spacing of secondary stiffeners, in mm
l = length of the plate panel, in metres
γ = convex curvature correction, *see* Pt 6, Ch 2,2.4
β = aspect ratio correction, *see* Pt 6, Ch 2,2.5

Note: The plate bending stresses are to be based on the actual stiffener spacing.

2.2.3 The direct stress in a plate panel subjected to membrane or in-plane loading is to be calculated as follows:

$$\sigma_x = \frac{10L}{A}\ \text{N/mm}^2$$

where

L = in-plane load on the panel of plating, in kN
A = area normal to the load, L, in cm^2, ignoring secondary stiffeners which are not continuous but may include deep beams.

2.2.4 The shear stress in a plate panel is to be calculated as follows:

$$\tau_{xy} = \frac{10Q}{A}\ \text{N/mm}^2$$

where

Q = shear force acting on the panel of plating
A = cross-sectional area of the panel in the direction of the shear force, in cm^2
= $t_p\,b_v$ or $t_p\,b_t$

b_t and b_v are the total breadth of the plate panel over which the shear force acts.

2.3 Stresses in secondary and primary member stiffeners

2.3.1 The bending stresses, deflection and shear stress in stiffeners or beams due to lateral pressure loading or point loads are to be derived as given below.

2.3.2 The stresses in the stiffener flange, σ_{sf}, and the attached plating to the stiffener, σ_{sp}, due to the applied load are illustrated in Fig. 3.2.2 and may be derived using the formulae given below.

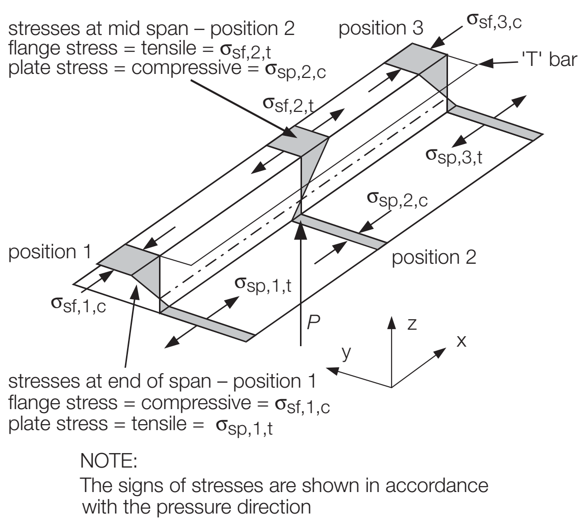


Fig. 3.2.2 Bending stresses in stiffener beam

2.3.3 **Bending stresses**

Bending stress due to a lateral pressure load

$$\sigma_{sf,j} = + \frac{\Phi_{Zj}\, p\, s_p\, l_e^2}{Z_f} \text{ N/mm}^2$$

$$\sigma_{sp,j} = - \frac{\Phi_{Zj}\, p\, s_p\, l_e^2}{Z_p} \text{ N/mm}^2$$

Bending stress due to a point load or force

$$\sigma_{sf,j} = + \frac{10^3\, \Phi_{Zj}\, F\, l_e}{Z_f} \text{ N/mm}^2$$

$$\sigma_{sp,j} = - \frac{10^3\, \Phi_{Zj}\, F\, l_e}{Z_p} \text{ N/mm}^2$$

Bending stress due to an applied end deflection

$$\sigma_{sf,j} = + \frac{\Phi_{Zj}\, \delta\, \mathrm{EI}}{10^5\, l_e^2\, Z_p} \text{ N/mm}^2$$

$$\sigma_{sp,j} = - \frac{\Phi_{Zj}\, \delta\, \mathrm{EI}}{10^5\, l_e^2\, Z_f} \text{ N/mm}^2$$

2.3.4 **Beam deflection**

Deflection in beam due to a lateral pressure load

$$\delta_{s,j} = \frac{10^5\, \Phi_{Ij}\, p\, s_p\, l_e^4}{EI} \text{ mm}$$

Deflection in beam due to point load

$$\delta_{s,j} = \frac{10^8\, \Phi_{Ij}\, F\, l_e^3}{EI} \text{ mm}$$

2.3.5 **Shear stresses**

Shear stress in beam due to a lateral pressure load

$$\tau_{s,j} = \frac{\Phi_{Aj}\, p\, s_p\, l_e}{100 A_w} \text{ N/mm}^2$$

Shear stress in beam due to a point load

$$\tau_{s,j} = \frac{10\, \Phi_{Aj}\, F}{A_w} \text{ N/mm}^2$$

Shear stress in beam due to an applied end deflection

$$\tau_{s,j} = \frac{\Phi_{Aj}\, EI\, \delta}{10\, l_e^3\, A_w} \text{ N/mm}^2$$

where

j = position along stiffener beam, where j =1, 2 or 3, *see* Pt 6, Ch 2,2, Table 2.2.1 and Fig. 3.2.2

Φ_{Zj}, Φ_{Ij} and Φ_{Aj} are the section modulus inertia and shear web area coefficients dependent on the loading model assumption, *see* Pt 6, Ch 2,2, Table 2.2.1, and the position along the stiffener beam

p = lateral pressure, in kN/m^2

F = applied force, in kN

δ = applied deflection, in mm

l_e = effective span length of the stiffener or primary member, in metres, *see* Pt 6, Ch 2,2.6

s_p is the stiffener spacing, in mm

s_p is to be taken as s for secondary stiffeners and 1000S for primary members, *see* Pt 6, Ch 2,1.3.1

Z_f and Z_p are the section moduli, in cm^3, of the stiffener including attached plating at the flange and attached plating respectively

I = section modulus, in cm^4

A_w = web area of stiffener, in cm^2

E = modulus of elasticity, in N/mm^2.

2.3.6 The suffices ',*t*' and ',*c*' refer to the tensile or compressive values of bending stress in the stiffener which arise due to the stiffener end condition restraints, *see* Fig. 3.2.2.

■ *Section 3* **Stress analysis model**

3.1 General

3.1.1 The stress analysis model given in this section is to be applied to the total design loads determined in accordance with Chapter 2.

3.1.2 The stresses, deflections and other values are to be determined for all load cases and all the design load combinations specified in Ch 2,3.

3.2 Stress determination in primary members

3.2.1 Primary members are major structural members and provide support to decks, major equipment, etc., and also control the cross-sectional and longitudinal shape between decks, side shell and bulkheads. The major primary members are listed in the paragraphs below.

3.2.2 The following structural items are classed as longitudinal primary members:

- Double bottom girders with attached bottom shell and inner bottom plating.
- Single bottom girders with attached bottom shell plating.
- Deck girders.
- Longitudinal stringers with attached side shell or longitudinal bulkhead plating.
- Horizontal diaphragms with attached side shell and inner skin plating.

3.2.3 The following structural items are classed as vertical primary members:

- Deep web frames supporting the side shell or bulkheads including attached plating.
- Double skin web frames including the attached side shell and inner skin plating.
- Deep vertical bulkhead stiffeners.

3.2.4 The following structural items are classed as transverse primary members:

- Double bottom floors with bottom shell and inner bottom plating.
- Single bottom floors with bottom shell plating.
- Deep deck or transverse beams with attached deck plating.
- Double skin deck beam with attached upper and lower deck plating.
- Transverse bulkhead stringers with attached bulkhead plating.

3.2.5 Primary members support the secondary members and can be considered to act independently of the secondary members. They need to be considered as a large beam supporting local loads with the global and local membrane stresses in the attached plating.

3.2.6 A typical primary member will consist of:

- Primary attached plating, e.g. bottom shell providing local bending capability.
- Web plate, providing shear capability.
- Upper flange or plating for double skin construction providing local bending capability.

The stresses in the attached plating and flange are to be derived in accordance with the requirements of this Section. The stresses in the web plating are to be determined in accordance with 3.3, or 3.4 if it is of grillage construction.

3.2.7 The stresses in primary members are to be derived using the recommended equations and stiffener end conditions given in Table 3.3.1. The stress components used in deriving the primary member stresses are given below.

3.2.8 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.2.9 In general, a primary member will be subject to the following loads:

- In-plane or axial loading as a consequence hull girder loads, transverse loading due to side shell pressure loads or vertical support loads.
- Bending loads due to the member supporting out of plane external and internal pressures and equipment or cargo loadings.

3.2.10 The in-plane or axial loading in the primary member attached plating and flanges is to be taken as the membrane stress derived in accordance with the following:

(i) For longitudinally effective primary members:
σ_{hg} is the longitudinal stress due to hull girder bending

$$\sigma_{hg} = \frac{z_{na} M_D}{1000 I_{hg}} \text{ N/mm}^2$$

(ii) For primary members in the transverse direction:
σ_{yg} is the membrane stress due to a global load of *LT*

$$\sigma_{yg} = \frac{10\,LT}{A} \text{ N/mm}^2$$

(iii) For primary members in the vertical direction:
σ_{xv} is the membrane stress due to a vertical load of *LV*

$$\sigma_{xv} = \frac{10\,LV}{A} \text{ N/mm}^2$$

where

M_D = design hull girder bending moment given in Ch 2,3
z_{na} = vertical distance above the neutral axis of the structural member under consideration, in metres
I_{hg} = the section inertia at the longitudinal position under consideration, *see* Pt 6, Ch 4,2.3, in m^4
A is the total area, in cm^2, of the primary member including the full breadth of attached plating

LT and *LV* are defined in Ch 2,2.1.1.

3.2.11 The out of plane bending loads to be applied to the primary member are specified in Chapter 2. For example, the out of plane bending load for a double bottom girder is specified in Ch 2,4.6.7. In this case the pressure components are to be uniformly distributed over the double bottom girder beam with the point loads applied as individual forces.

3.2.12 The stresses in the flange and attached plating due to bending of the primary member are to be derived as follows:

σ_{xb} is the stress in the plating due to bending of the primary member beam/plate combination under lateral pressure loading or lateral inertial loads
σ_{xb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the primary member axial stress is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when is the axial stress positive
When appropriate the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ are the maximum compressive and tensile stresses in the attached plating of the primary member and are to be derived using the bending stress equations in 2.3.3, *see also* 2.3.6.

3.2.13 The section modulus of the primary member with regard to local bending properties is to be derived in accordance with Pt 6, Ch 2,2.3 with effective breadths of attached plating as given by Pt 6, Ch 2,2.2.

3.2.14 The total equivalent stress or von Mises stress, σ_{vm}, is to be derived using the following formula:

$$\sigma_{vm} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_y\,\sigma_x + 3\,\tau_{xy}^2} \text{ N/mm}^2$$

3.3 Stress determination in primary/secondary systems

3.3.1 The primary members support the secondary members. The secondary stiffeners transfer the lateral loads into the primary members.

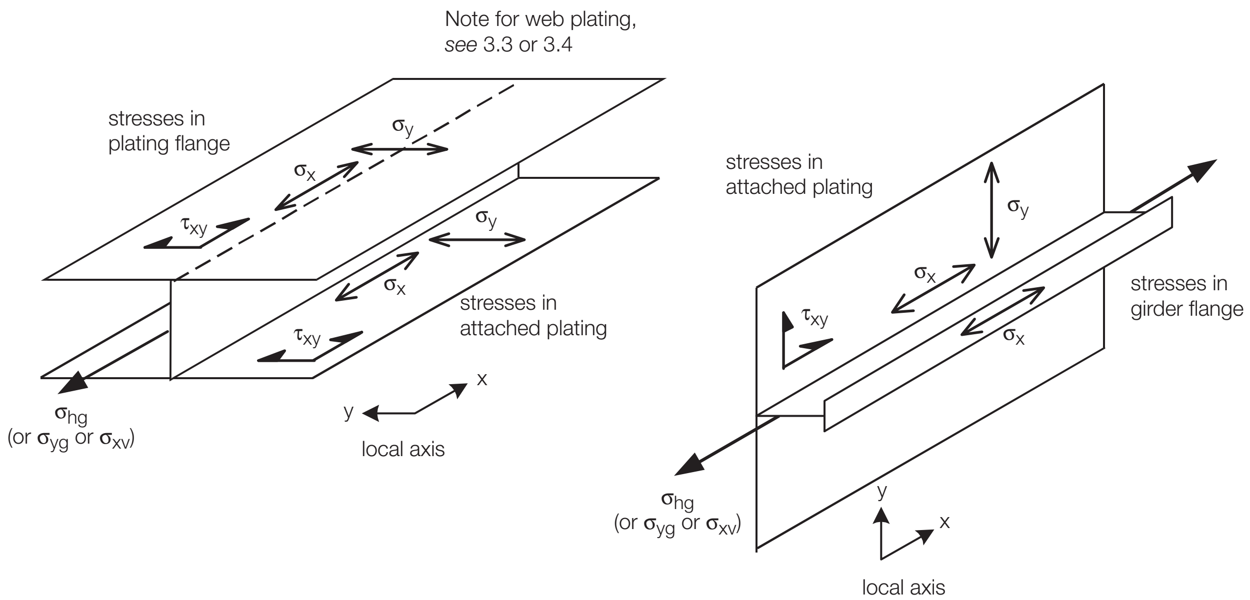
3.3.2 An example of a primary/secondary plating and stiffener system is as follows: a longitudinal spacing of 600 mm and a transverse spacing of 2000 mm with the transverse stiffeners having an section inertia value of five times the secondary longitudinal stiffeners.

3.3.3 In a primary/secondary system it is normally sufficient to consider the secondary stiffeners as acting independently of the primary stiffeners. Hence the total stress analysis can ignore the effects of bending of the primary members.

3.3.4 The total stress analysis can be based on the plating between the primary transverse members and need only consider plating membrane stresses and bending stresses in secondary members.

Table 3.3.1 Stress determination in primary members

Stress direction *see* Note 1	Stress equation	Stiffener end condition	Notes
Longitudinal primary members			
σ_x	$\sigma_x = \sigma_{hg} + \sigma_{xb}$ N/mm^2	Built In	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{yg}$ N/mm^2 (attached to deck plating) $\sigma_y = \sigma_{xv}$ N/mm^2 (attached to side shell or long bhd plating)	N.A.	Only applicable to the attached plating
τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see* 3.3 or 3.4	—	Only applicable to the attached plating
Transverse primary members			
σ_x	$\sigma_x = \sigma_{yg} + \sigma_{xb}$ N/mm^2	Built In	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{hg}$ N/mm^2 (attached to deck plating) $\sigma_y = \sigma_{xv}$ N/mm^2 (attached to transverse bulkhead plating	N.A.	Only applicable to the attached plating
τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see* 3.3 or 3.4	—	Only applicable to the attached plating
Vertical primary members			
σ_x	$\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	Built In	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{hg}$ N/mm^2 (attached to side shell or long bhd plating) $\sigma_y = \sigma_{yg}$ N/mm^2 (attached to transverse bulkhead plating)	N.A.	Only applicable to the attached plating
τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see* 3.3 or 3.4	—	Only applicable to the attached plating
Symbols			
σ_x is along the span of the primary member σ_y is in the normal direction to the span in the attached plating τ_{xy} is only applicable to the attached plating	σ_{hg}, σ_{yg} and σ_{xv} are given in 3.2.10 σ_{xb} is given in 3.2.12		



3.3.5 The stresses in the plating of a primary/secondary plating system are to be derived using the recommended equations and stiffener end conditions given in Tables 3.3.2 and 3.3.3. The stresses in the flanges of panel stiffeners are given in 2.3.6 using the conditions given in Tables 3.2.3 and 3.3.3. The stresses and nomenclature are shown in Fig. 3.3.1.

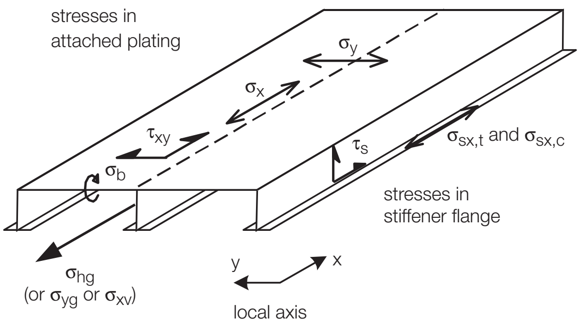


Fig. 3.3.1
Definition of stresses in a primary/secondary stiffened panel

3.3.6 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.3.7 Buckling of plating is to be assessed using the in-plane membrane stresses only. The membrane stresses are to be derived as follows:

σ_x using Equation B
σ_y using Equation D
τ_{xy} using Equation E

where
Equations B, D and E are defined in Table 3.3.2.

3.4 Stress determination in grillage systems

3.4.1 A grillage system of plating and stiffeners is one where the bending stiffness of the orthogonal stiffeners are similar in magnitude and the orthogonal stiffeners work together to support the applied loads. The grillage system is in turn supported by primary structural items such as deep girders, deep transverse beams or bulkheads.

3.4.2 An example of a grillage system is as follows: plating supported by a longitudinal spacing of 600 mm and a transverse spacing of 1500 mm with the transverse stiffeners having an section inertia value of 1,5 times the longitudinal stiffeners.

3.4.3 Normally it is necessary to use direct calculations to evaluate the stresses within a grillage plating system. However it may be sufficient to consider the stiffeners perpendicular to an edge of the grillage panel as acting independently of the grillage system. *See* Table 3.3.4 and Methods FF and GG in the attached figure, also Methods II and JJ in Table 3.3.5.

3.4.4 The bending stresses in the edge stiffeners may be evaluated on the basis of encastre at the edge of the grillage panel and no rotation and free to deflect at the intersection with the first orthogonal stiffener.

3.4.5 In this case, the total stress analysis is to be based on the membrane stress in the plating of the grillage panel and consider the bending stresses in the middle stiffener perpendicular to the edge of the panel.

3.4.6 It will be necessary to derive the total stress at the edge of the panel for each stiffener direction.

3.4.7 The total stress in the centre of the grillage panel should also be checked. In this case it is necessary to consider the stresses in the plate due to bending of the stiffener in each direction as well as the plating stresses due to membrane loads.

3.4.8 The stresses in the plating of a grillage plating system are to be derived using the recommended equations and stiffener end conditions given in Tables 3.3.4 and 3.3.5. The stresses in the flanges of the panel stiffener are given by 2.3.6 using the conditions given in Tables 3.3.4 and 3.3.5. The stresses are illustrated in Fig. 3.3.2.

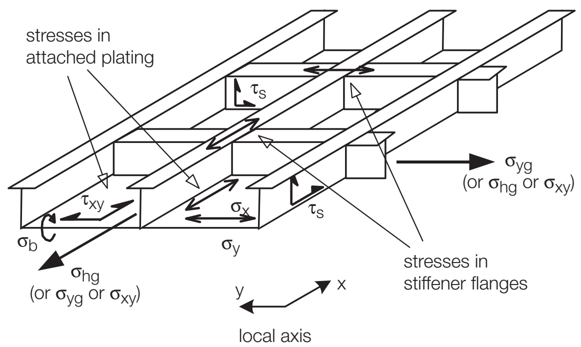


Fig. 3.3.2
Definition of stresses in a grillage stiffened panel

3.4.9 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.4.10 Buckling of plating is to be assessed using the in-plane membrane stresses only. The membrane stresses are to be derived as follows:

σ_x using Equation B
σ_y using Equation D
τ_{xy} using Equation E

where
Equations B, D and E are defined in Table 3.3.4.

Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g. decks and longitudinal bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method AA Longitudinal secondary stiffeners			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	
Method BB Longitudinal secondary stiffeners adjacent to bulkhead			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2		Edge end built in. Other end free to deflect,no rotation, *see* Note 2
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	
Method CC Transverse secondary stiffeners			
σ_x	**Equation B** $\sigma_x = \sigma_{xg}$ N/mm^2	N.A.	N.A.
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	

NOTES
1. The parameters for Equations A to E are given in 3.5 to 3.7.
2. Alternatively the deflection from the transverse member over its full span, excluding the support from longitudinal stiffeners, may be applied.

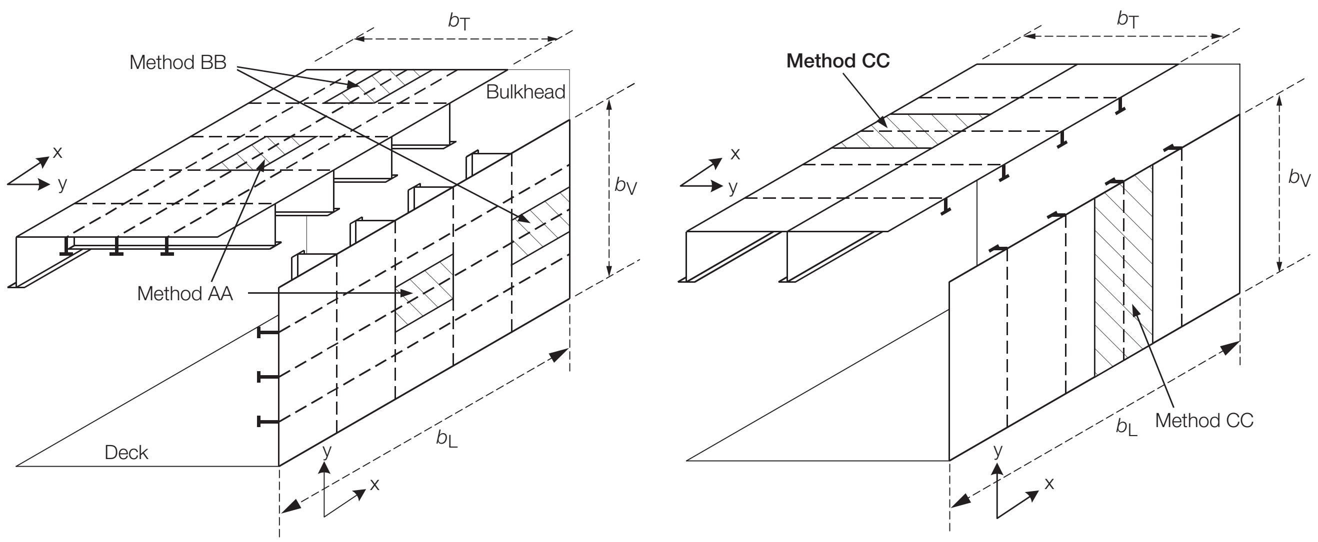


Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g. transverse bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method DD Vertical secondary stiffeners			
σ_x	**Equation H** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	N.A.
σ_y	**Equation G** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	Built in
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	
Method EE Horizontal secondary stiffeners			
σ_x	**Equation I** $\sigma_x = \sigma_{xv}$ N/mm^2	N.A.	N.A.
σ_y	**Equation F** $\sigma y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	

NOTE
The parameters for Equations F to J are given in 3.8 to 3.10.

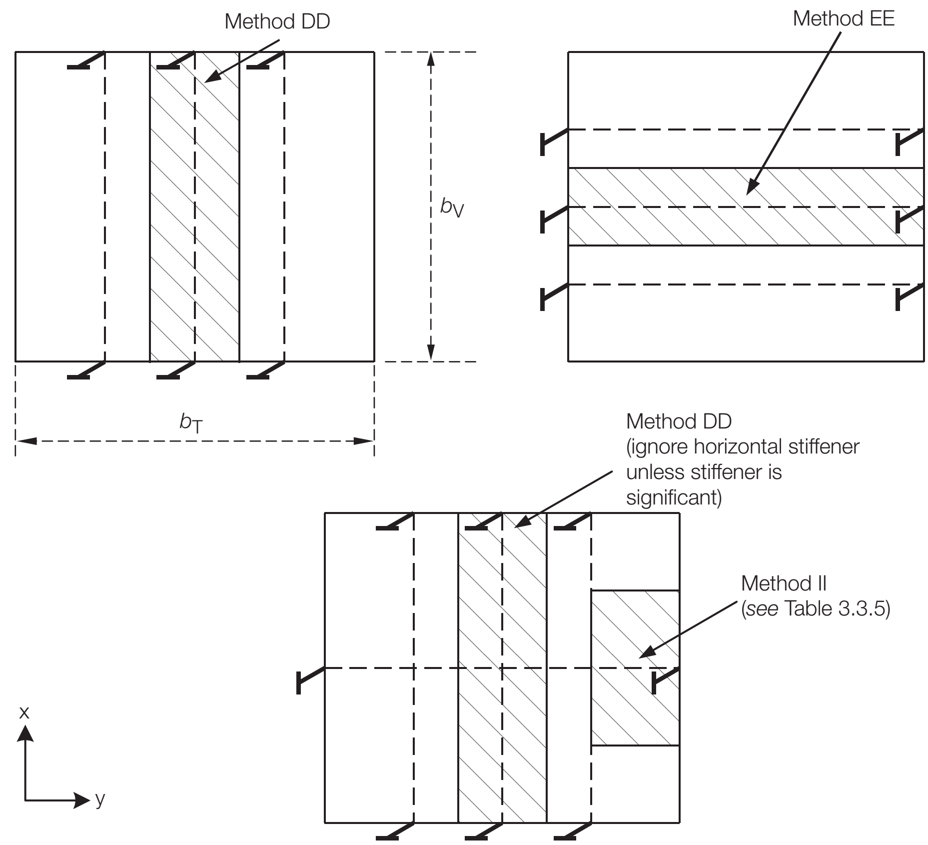


Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g. decks and longitudinal bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method FF	At the fore and aft edges of a grillage panel		
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	Edge end built in. Other end free to deflect, no rotation, *see* Note 2
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	
Method GG	At the port and starboard edges of a grillage panel		
σ_x	**Equation B** $\sigma_x = \sigma_{xg}$ N/mm^2	N.A.	N.A.
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx} *see* 3.11	Edge end built in. Other end free to deflect, no rotation, *see* Note 3
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	
Method HH	At the centre of a grillage panel		
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	

NOTES
1. The parameters for Equations A to E are given in 3.5 to 3.7.
2. Alternatively the deflection from the longitudinal member over its full span, excluding the support from transverse stiffeners, may be applied.
3. Alternatively the deflection from the transverse member over its full span, excluding the support from longitudinal stiffeners, may be applied.

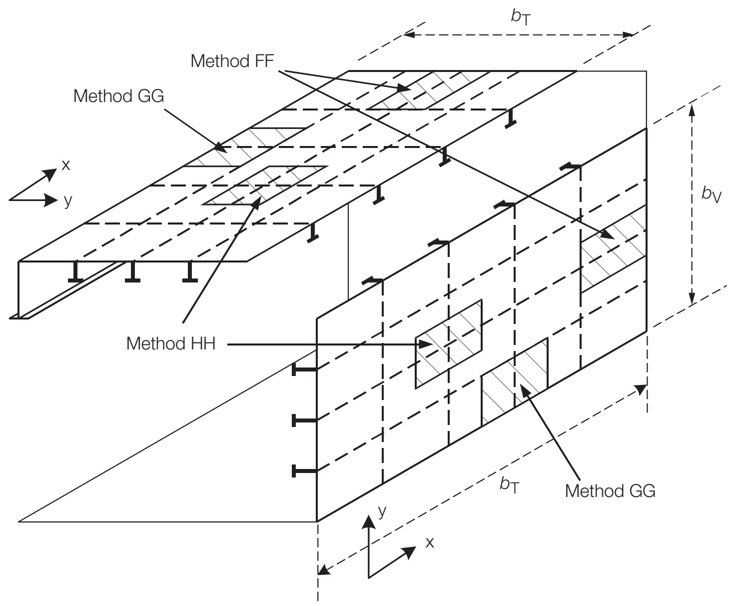
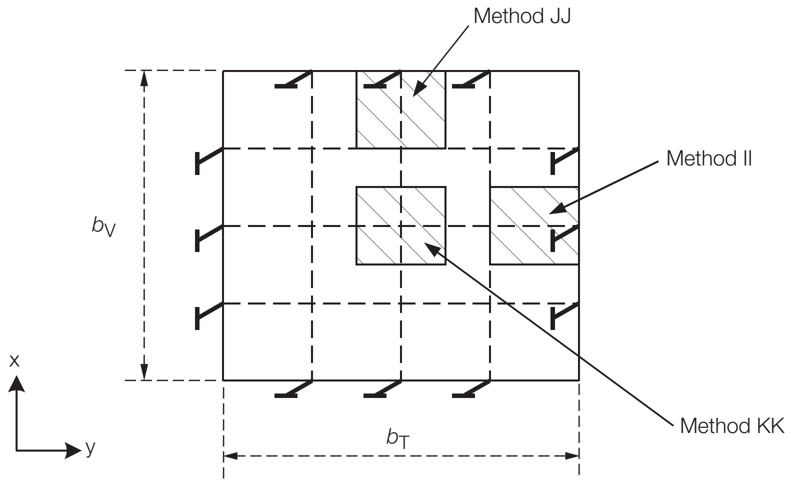


Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g. transverse bulkheads.

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method II Horizontal stiffeners at the port and starboard edges of a grillage panel			
σ_x	**Equation I** $\sigma_x = \sigma_{xv}$ N/mm^2	N.A.	Edge end Built in Other end free to deflect, no rotation, *see* Note 2
σ_y	**Equation F** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx} *see* 3.11	N.A.
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	—
Method JJ Vertical stiffeners at the top and bottom edges of a grillage panel			
σ_x	**Equation H** $\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	N.A
σ_y	**Equation G** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	Edge end Built in Other end free to deflect, no rotation, *see* Note 3
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	—
Method KK At the centre of a grillage panel			
σ_x	**Equation H** $\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	σ_{sx} *see* 3.11	Built in
σ_y	**Equation F** $\sigma_y = \sigma_{yg} + \sigma_{yb} + \sigma_{yf}$ N/mm^2	σ_{sx} *see* 3.11	Built in
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \dfrac{QT}{t_b\, b_T} + \dfrac{QV}{t_b\, b_V}$ N/mm^2	δ_s *see* 2.3.4 τ_s *see* 2.3.5	—

NOTES
1. The parameters for Equations F to J are given in 3.8 to 3.10.
2. Alternatively the deflection of the vertical member over its full span, excluding the support from horizontal stiffeners, may be applied instead of the free to deflect condition.
3. Alternatively the deflection from the horizontal member over its full span, excluding the support from vertical stiffeners, may be applied instead of the free to deflect condition.



3.5 Derivation of the combined longitudinal stress on panels subjected to hull girder bending

3.5.1 The longitudinal stresses in the plating and stiffener flanges for structural members subjected to hull girder bending loads as well as lateral loads are to be derived using the equations specified in this Section, *see* Tables 3.3.2 and 3.3.4.

3.5.2 **Equation A** is used for grillage systems or plating systems with the secondary stiffeners orientated in the longitudinal direction. For these systems, the stress in the plating/stiffener combination due to local bending needs to be considered in addition to the membrane stresses due to hull girder bending. The stress components in Equation A are given below.

3.5.3 **Equation B** is used for plating systems with the secondary stiffeners orientated in the transverse (or vertical) direction. For these systems only the longitudinal stress due to hull girder bending needs to be considered.

3.5.4 The longitudinal stress components associated with Equations A and B are given below:

σ_{xg} is the longitudinal membrane stress due to hull girder bending

$$= \frac{Z_{na}\,M_D}{1000\,I_{hg}} \text{ N/mm}^2$$

σ_{xb} is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads
Normally σ_{xb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the hull girder bending stress σ_{xg} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{xg} is positive, *see* Fig. 3.2.2. However, there may be cases where it is necessary to consider the opposite situation
When appropriate the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in 2.3.3, *see also* 2.3.6

M_D = design hull girder bending moment, in kNm given in Ch 2,3

z_{na} = vertical distance above the neutral axis of the structural member under consideration, in metres

I_{hg} = the section inertia at the longitudinal position under consideration, *see* Pt 6, Ch 4,2, in m^4.

3.6 Derivation of the combined transverse stress acting on panels subjected to hull girder bending

3.6.1 The transverse stresses in the plating and stiffener flanges for structural members subjected to transverse loads as well as lateral loads are to be derived using the equations specified in this Section, *see* Tables 3.3.2 and 3.3.4.

3.6.2 **Equation C** is used for grillage systems or plating systems with the secondary stiffeners orientated in the transverse direction. For these systems, the stress in the plating/stiffener combination due to local bending needs to be considered in addition to membrane stresses due to global transverse loading. The stress components in Equation C are given below

3.6.3 **Equation D** is used for plating systems with the secondary stiffeners orientated in the longitudinal direction. For these systems, only membrane stress due to global transverse loading needs to be considered.

3.6.4 The transverse stress components associated with equations C and D are given below:

σ_{yg} is the membrane stress due to global transverse loading

$$= \frac{LT}{t_p\,b_L} \text{ N/mm}^2$$

σ_{yb} is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads
Normally σ_{yb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the global transverse stress σ_{yg} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{yg} is positive, *see* Fig. 3.3.2. However, there may be cases where it is necessary to consider the opposite situation.
When appropriate the σ_{yb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in 2.3.3, *see also* 2.3.6

LT is the appropriate transverse design load, in kN, given in Chapter 2, i.e. LT_{DK}, LT_{BS}, etc.

t_p = thickness of plating, in mm

b_L = breadth of plating, in m, over which the load LT applies. Normally this is the distance between decks or the height of the plating panel.

3.7 Derivation of the total shear stress

3.7.1 **Equation E** is used to derive the total shear stress in the plating for all plating systems.

3.7.2 The shear stress components associated with Equation E are given below:

$|Q|$ denotes the absolute value of parameter Q

$$\tau_{hg} = \frac{|Q_D|\,A_z}{I_{hg}\,\delta_i} \text{ N/mm}^2$$

Q_D is global hull girder shear force, in kN. This will be zero for all transverse plating systems

Q_D is given in Ch 2,3

QT = local shear force due to local transverse loads, in kN, given in Chapter 2, e.g. QT_{DK}, QT_{ST}

QV = local shear force due to local inertial forces, in kN, given in Chapter 2, e.g. QV_{DG}, QV_{BG}

A_z, I_{hg} and δ_i are given in Pt 6, Ch 4,2.3.5

b_V, b_T = total breadth over which the shear force acts, typically the height or breadth of the plating panel, in metres, *see* Tables 3.3.2 or 3.3.4.

NOTE

All shear force loads are to be assumed positive.

3.8 Derivation of the combined transverse stress acting on transversely orientated panels

3.8.1 The transverse stresses in the plating and stiffener flanges for structural members subjected to transverse loads as well as lateral loads are to be derived using the equations specified in this Section, *see* Tables 3.3.3 and 3.3.5.

3.8.2 **Equation F** is used for grillage systems or plating systems with the secondary stiffeners orientated in the transverse direction.

3.8.3 **Equation G** is used for plating systems with the secondary stiffeners orientated in the vertical direction.

3.8.4 The transverse stress components associated with Equations F and G are given in 3.6.4.

3.9 Derivation of the combined vertical stress acting on transversely orientated panels

3.9.1 The vertical stresses in the plating and stiffener flanges for structural members subjected to vertical loads as well as lateral loads are to be derived using the equations specified in this Section, *see* Tables 3.3.3 and 3.3.5.

3.9.2 **Equation H** is used for grillage systems or plating systems with the transverse secondary stiffeners orientated in the vertical direction.

3.9.3 **Equation I** is used for plating systems with the secondary stiffeners orientated in the transverse direction.

3.9.4 The vertical stress components associated with Equations H and I are given below:

σ_{xv} is the membrane stress due to vertical loading

$$= \frac{LV}{t_p\,b_T} \text{ N/mm}^2$$

σ_{xb} is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads

Normally σ_{xb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the vertical stress σ_{xv} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{xv} is positive, *see* 3.2.2. However, there may be cases where it is necessary to consider the opposite situation

When appropriate the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in 2.3.3, *see also* 2.3.6

where

LV is the design load, in kN, given in Chapter 2, e.g. LV_{SS}, LV_{BH}

t_p = thickness of plating, in mm

b_T = breadth of plating, in m, over which the load LV applies. Normally, this is the distance between the side shell(s) or longitudinal bulkheads but it is to be reduced for the presence of large openings.

3.10 Derivation of the total shear stress on transversely orientated panels

3.10.1 **Equation J** is used to derive the total shear stress in any plating system which is not subjected to global hull girder shear force.

3.10.2 The shear stress components associated with Equation J are given below:

QT = local shear force due to local transverse loads, in kN, given in Chapter 2, e.g. QT_{DK}, QT_{SF}, QT_{ST}

QV = local shear force due to local inertial forces, in kN, given in Chapter 2, e.g. QV_{BM}, QV_{DG}, QV_{BG}, QV_{FL}

B_V, B_T = total breadth, in m, over which the shear force acts, *see* Tables 3.3.3 or 3.3.5.

NOTE

All shear force loads are to be assumed positive.

3.11 Derivation of total stresses in stiffener flanges

3.11.1 The total compressive and tensile stresses in stiffener flanges, σ_{sx}, are given by the following:

$$\sigma_{sx,c} = \sigma_{ax} + \sigma_{sf,c} \text{ N/mm}^2 \text{ (compressive)}$$

$$\sigma_{sx,t} = \sigma_{ax} + \sigma_{sf,t} \text{ N/mm}^2 \text{ (tensile)}$$

where

σ_{ax} is the axial stress in the stiffener at the combined stiffener plate neutral axis, this is normally to be taken as the membrane stress in the plating, i.e. σ_{xg}, σ_{yg} or σ_{xv} depending on the orientation of the stiffener, *see* 3.5.4, 3.6.4 or 3.9.4

$\sigma_{sf,t}$, $\sigma_{sf,c}$ are the tensile and compressive bending stresses is the stiffener flange, *see* 2.3.3 and 2.3.6, using the appropriate boundary conditions given in Section 3.

3.11.2 These formulae may be applied to grillage and primary/secondary stiffened plating systems. The stresses in a stiffener beam subjected to more than one load may be derived by adding the stresses from each load component.

3.12 Derivation of total equivalent stress

3.12.1 The total equivalent stress or von Mises stress, σ_{vm}, is to be derived using the following formula:

$$\sigma_{vm} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_y \sigma_x + 3\,\tau_{xy}^2} \text{ N/mm}^2.$$

■ *Section 4* Structural design factors

4.1 General

4.1.1 This Section gives the allowable design criteria to be used to assess the structure for maximum and minimum stresses and other values derived in accordance with the **TLA** method.

4.1.2 The allowable design criteria are also to be used when direct calculation or similar methods are used as an alternative to the **TLA** stress analysis model in Section 3.

4.1.3 The allowable design criteria are applicable for all ships including NS1 ships.

4.2 Design criteria for the Total Load Assessment (TLA) approach

4.2.1 The stresses in the plating and stiffeners that have been derived using the **TLA** method are to be less that the allowable stresses and other design criteria given in this section. For all areas of the structure, the modes of failures specified in Tables 3.4.1 to 3.4.4 are to be satisfied. *See also* 4.3 for presentation of results.

4.2.2 In order to satisfy the requirements, the ratio of the actual stress to the allowable stress or load utilisation factor is to be less than 1,0, similarly for the deflection and buckling utilisation factors. Hence

σ/σ_a <1,0
λ/λ_a <1,0
δ/δ_a <1,0

where

σ is the actual stress value
σ_a is the allowable stress value, *see* 4.2.3
λ is the actual buckling factor of safety achieved
λ_a is the allowable buckling factor of safety, *see* 4.2.4
δ is the actual deflection
δ_a is the allowable deflection value, *see* 4.2.5.

4.2.3 The allowable stresses are to be derived using the following formulae:

- Direct or bending allowable stress
  $\sigma_a = f_1\, f_{hts}\, \sigma_o$ N/mm^2
- Shear allowable stress
  $\tau_a = f_1\, f_{hts}\, \tau_o$ N/mm^2

where

f_1 is taken from Table 5.3.2 in Pt 6, Ch 5, as specified below:

- Table 3.4.1 for plating.
- Table 3.4.2 for stiffeners.
- Table 3.4.3 for plate panels.
- Table 3.4.4 for primary members.

f_{hts} = correction factor for high tensile steel, *see* Pt 6, Ch 5,1.3
σ_o is the minimum yield stress
τ_o is the minimum shear yield stress.

Table 3.4.1 Design criteria for plating

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in Pt 6, Ch 5 Table 5.3.2
	Stress criteria		
σ_b	Bending stress in plate due to lateral pressure, *see* 2.2.2	Local stress requirements	σ_b
σ_x	Longitudinal membrane stress in plate including the stresses due to stiffener bending, *see* 3.3 or 3.4	Hull girder bending requirements	σ_x
σ_y	Transverse (or vertical) membrane stress in plate, *see* Section 3	None	None
τ_{xy}	Shear stress due to global and local loads, *see* Section 3	Hull girder shear requirements	τ_{xy}
σ_{vm}	Combined total equivalent stress in plate, *see* 3.12	Yield stress criterion	σ_{vm}
	Buckling criteria		
σ_{xg}, σ_{yg}, or σ_{xv}	Compressive membrane stress, *see* 3.3 or 3.4	Uni-axial buckling, *see* Pt 6, Ch 2,4.3	λ_σ
τ_{xy}	Shear stress, *see* Section 3	Shear buckling, *see* Pt 6, Ch 2,4.3	λ_τ
σ_x, σ_y, τ_{xy}	Bi-axial and shear stress field, *see* Section 3	Bi-axial and shear buckling , *see* Pt 6, Ch 2,4.3	λ_σ and λ_τ

Table 3.4.2 Design criteria for stiffeners

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in Pt 6, Ch 5 Table 5.3.2
	Stress criteria		
$\sigma_{sx,t}$	Maximum tensile (+ve) bending stress in flange of stiffener, *see* 3.11	Elastic stress criteria - local loads only hull girder and local loads	σ_x σ_{vm}
$\sigma_{sx,c}$	Maximum compressive (-ve) bending stress in flange of stiffener, *see* 3.11	Elastic stress criteria - local loads only hull girder and local loads	σ_x σ_{vm}
	Buckling criteria		
σ_{ax}	Overall axial stress, *see* 2.3.11	Buckling control column, flange, web, torsional, tripping modes of buckling, *see* Pt 6, Ch 2,4.7	λ_σ
$\sigma_{sx,c}$	Maximum compressive (-ve) bending stress in flange of stiffener, *see* 3.11	Buckling of flange, *see* Pt 6, Ch 2,4.7	λ_σ
	Other criteria		
τ_s	Shear stress in web, *see* Tables 3.3.2 to 3.3.5	Shear stress criteria for web area	τ_{xy}
δ_s	Deflection of stiffener due to lateral bending, *see* Tables 3.3.2 to 3.3.5	Inertia/deflection criteria	f_δ

Table 3.4.3 Design criteria for stiffened panels

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in Pt 6, Ch 5 Table 5.3.2
	Buckling criteria		
σ_{xg}, σ_{yg}, or σ_{xv}	Membrane stress	Overall panel buckling, *see* Pt 6, Ch 2,4.8	λ_σ
τ_{xy}	Shear stress	Shear buckling of stiffened panels, *see* Pt 6, Ch 2,4.6	λ_τ
	Other criteria		
δ_s	Deflection of panel due to lateral bending, *see* 2.3.4	Inertia/deflection criteria	f_δ

4.2.4 The buckling design safety factors are given in Pt 6, Ch 5.3, Table 5.3.2 and are to be used in conjunction with the buckling requirements specified in Pt 6, Ch 2,4. The required values of safety factors λ_σ and λ_τ are as specified by f_1 in 4.2.3.

$\lambda_a = f_1$

where

f_1 is taken from Pt 6, Ch 5.3, Table 5.3.2 as specified in 4.2.3.

4.2.5 The limiting deflection requirements for stiffening members specified in Tables 3.4.1 to 3.4.4 are to be satisfied. The allowable deflection criteria are expressed as a deflection/span ratio and the actual deflection is to be less than the allowable deflection, δ_a, where δ_a is as follows:

$\delta_a = f_1 \, l_e$ mm

where

f_1 is taken from Pt 6, Ch 5.3, Table 5.3.2 as specified in 4.2.3.

l_e = effective span length, in metres.

4.2.6 The assessment of scantling requirements to satisfy the impact or slamming pressure loads for plating and stiffening is given in Pt 6, Ch 3,14 and 15.

Table 3.4.4 Design criteria for primary members

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in Pt 6, Ch 5 Table 5.3.2
	Stress criteria		
	Web plating of primary member, *see* 3.3 or 3.4		
σ_b	Bending stress due to lateral pressure	Local stress requirements	σ_b
σ_x	Longitudinal membrane stress including the stresses due to secondary stiffener bending	Hull girder bending requirements	σ_x
σ_y	Transverse (or vertical) membrane stress including the stresses due to secondary stiffener bending	Local stress requirements	σ_y
τ_{xy}	Shear stress due to global and local loads	Shear stress requirements	τ_{xy}
σ_{vm}	Combined total equivalent stress	Yield stress criterion	σ_{vm}
	Flanges of primary member, *see* 3.2		
σ_x	Maximum tensile (+ve) bending stress in plate or flange	Elastic stress criteria	σ_{vm}
σ_x	Maximum compressive (-ve) bending stress in plate or flange	Elastic stress criteria	σ_{vm}
σ_{vm}	Combined total equivalent stress	Yield stress criterion	σ_{vm}
	Buckling criteria of primary member		
σ_{hg}, σ_{yg}, or σ_{xv}	Compressive stress at neutral axis, excluding the stresses due to secondary stiffener bending	Buckling of primary girders, *see* Pt 6, Ch 2,4.9	λ_σ
τ_{xy}	Shear stress in web plating due to global and local loads	Shear buckling of girder webs, *see* Pt 6, Ch 2,4.10	λ_τ
σ_x, σ_y, τ_{xy}	Bi-axial and shear stress field in web plating	Bi-axial and shear buckling, *see* Pt 6, Ch 2,4.3	λ_σ and λ_τ
σ_x	Maximum compressive (-ve) bending stress in plate or flange	Buckling of plate flange, *see* Pt 6, Ch 2,4.3 or buckling of flange, *see* Pt 6, Ch 2,4.7	λ_σ
	Other criteria		
τ_{xy}	Shear stress of girder web	Shear stress criteria for web area	τ_{xy}
δ_s	Deflection of girder due to lateral bending, *see* 2.3.4	Inertia/deflection criteria	f_δ

4.3 Presentation of results

4.3.1 It is recommended that the capability of the structure is represented by one of the following methods:

(a) Load utilisation factor, LUF, derived as follows:

$$LUF = \frac{\text{actual value}}{\text{allowable value}}$$

e.g. the stress $LUF = \dfrac{\sigma}{\sigma_a}$

(b) Adequacy parameter, AP, defined as follows:

$$AP = \frac{1 - LUF}{1 + LUF}$$

where LUF is given above.

4.3.2 Table 3.4.5 shows a comparison of the adequacy parameter with the load utilisation factor.

Table 3.4.5 Adequacy parameter (AP)

LUF	AP
0,0	1,00
0,5	0,33
0,8	0,111
1,0	0,00
1,2	–0,091
1,5	–0,20
2,0	–0,33

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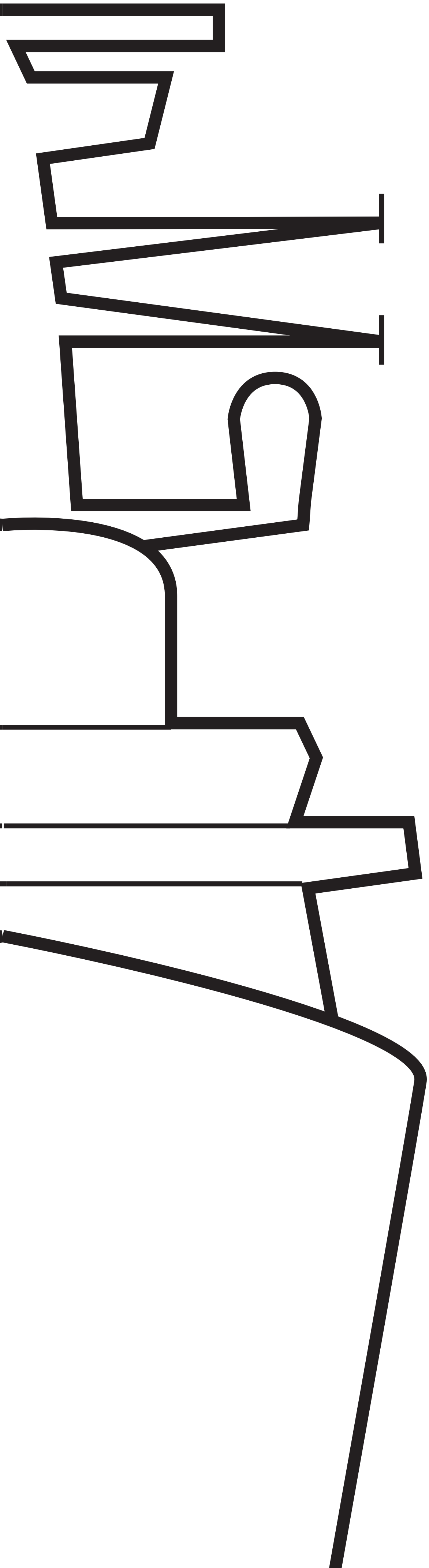


Rules and Regulations for the Classification of Naval Ships

Volume 2 *Parts 1–11*

Machinery and engineering systems

January 2005

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda. A dot-dash line indicates changes necessitated by International Conventions, Code of Practice or IACS Unified Requirements.

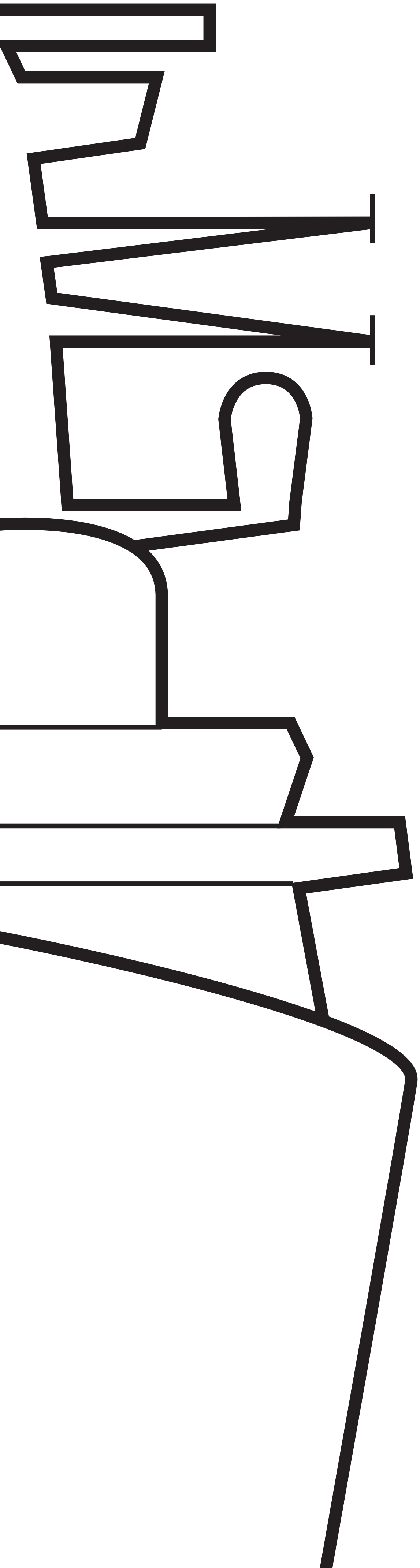
Rules programs

LR has developed windows based Rules Calculation Software which evaluates Rule Requirements for Special Service Crafts' structures. For details of this software please contact Lloyd's Register.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to Lloyd's Register's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2005



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 1*

General Requirements

January 2005

Lloyd's Register

Chapter Contents

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■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter covers the basis of the requirements for the design, construction, testing, installation, trials and through life changes of engineering systems installed in classed naval ships.

1.1.2 The requirements are applicable to mechanical, electrical, control, piping and pressure plant systems.

1.1.3 For the purposes of these Rules, an engineering system is considered to be a series of elements, including all equipment and associated sub-systems necessary to provide specified functions within the intended context of use in the system. Typical sub-systems include associated control and monitoring arrangements and their user interfaces, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

■ *Section 2* Engineering systems classification provisions

2.1 Provisions

2.1.1 The classification provisions for engineering systems installed in naval ships address the following:

(a) The suitability and functioning of equipment and systems for maintaining the watertight and weathertight integrity of the hull, and spaces within the hull.

(b) The safety and reliability of propulsion, steering and other essential engineering systems.

(c) The operation and functioning of systems installed for operational requirements relating to the ship type and additional Class notations.

(d) The effectiveness of systems which have been built into the ship in order to maintain basic conditions on board whereby appropriate stores, fuels, equipment and personnel can be safely carried whilst the ship is at sea, at anchor, or moored in harbour.

■ *Section 3* Engineering system designation

3.1 Categories

3.1.1 For the purpose of classification, an Engineering System is defined as any system that may be installed in a ship where such a system comprises one or more components. For the purpose of determining the appropriate assessment process for engineering systems in naval ships, there are three categories:

(a) Mobility.

(b) Ship Type.

(c) Ancillary.

3.1.2 Mobility category engineering systems are those systems installed in order for the ship to proceed on operations and are necessary for:

(a) The watertight and weathertight integrity of the hull and spaces within the hull.

(b) The safety and reliability of propulsion, steering and other essential auxiliary engineering systems.

3.1.3 Ship Type category engineering systems are those systems installed in order for the ship to carry out its in-service purpose and are necessary for:

(a) The operation and functioning of systems and equipment installed for purposes relating to the ship type.

(b) The operation and functioning of emergency machinery and equipment.

3.1.4 Ancillary category engineering systems are all systems other than Mobility category or Ship Type category, failure of which may compromise the provisions of Classification and are necessary for:

(a) The provision of basic conditions on board for the carriage of stores, fuels, equipment and personnel when the ship is at sea, at anchor, or moored in harbour.

3.1.5 Essential services are those necessary for the propulsion and safety of the ship within the Mobility and Ship Type categories defined in 3.1.2 and 3.1.3.

Section 4 Engineering system classification principles

4.1 Classification principles

4.1.1 Engineering system classification principles apply to all systems and equipment in order to achieve the provisions of classification. There are five groups of principles:
(a) Design principles.
(b) Construction principles.
(c) Installation and test principles.
(d) Trials principles.
(e) Through life operation principles.

4.2 Design principles

4.2.1 Systems are to be designed to minimise danger to persons on board.

4.2.2 Systems and equipment are to be designed in accordance with the requirements of the relevant parts of the Rules.

4.2.3 Systems are to be designed for the defined operating conditions that are to include static and dynamic loads.

4.2.4 Mobility category and Ship Type category engineering systems are to be provided with means to monitor and identify potential failures that could lead to catastrophic, hazardous or major consequences and to notify users of degradation in systems performance that could lead to failures.

4.2.5 Mobility category and Ship Type category engineering systems are to be provided with means to detect failures that could lead to catastrophic, hazardous or major consequences and to notify users of such failures.

4.2.6 Systems are to remain in, or revert to, a safe state when failure occurs.

4.2.7 Systems and equipment are to be so designed such that they can be maintained and repaired effectively and safely.

4.2.8 Systems are to be so designed that a single failure will not result in the flooding of a watertight compartment from the sea.

4.2.9 Systems are to be arranged so that a single failure in equipment or loss of an associated sub-system will not result in failure, contamination or degradation of another system leading to a dangerous situation or loss of a Mobility or Ship Type category system.

4.2.10 Mobility and Ship Type category systems are to be such that key functions can be maintained in the event of a single failure in an operational sub-system.

4.2.11 Systems are to be provided with effective means of operation and control for all intended functions under all normal and abnormal operational modes.

4.2.12 Systems are to be designed and installed to reduce the risk of fire to a level that is as low as reasonably practicable.

4.2.13 Systems are to be designed and installed to reduce the risk of pollution to a level that is as low as reasonably practicable.

4.3 Construction principles

4.3.1 The place of construction is to have suitable facilities for the construction and testing of engineering equipment and systems.

4.3.2 Construction is to be in accordance with plans approved by Lloyd's Register (hereinafter referred to as 'LR') in accordance with the requirements of the relevant parts of the Rules.

4.3.3 Where required by the Rules, items are to be constructed under survey.

4.3.4 Materials are to be approved and, manufactured and tested in accordance with a standard acceptable to LR.

4.3.5 Satisfactory operation and load testing is to be witnessed by LR where required by the Rules.

4.4 Installation and test principles

4.4.1 Installation is to be in accordance with plans approved by LR and relevant LR requirements.

4.4.2 Installation to be carried out under LR Survey.

4.4.3 Tests to be conducted in accordance with LR requirements.

4.4.4 Any alterations to approved plans are to be approved by LR.

4.4.5 Surveyable items not complying with approved plans or LR requirements are to be replaced or rectified.

4.5 Trials principles

4.5.1 A trials schedule is to be agreed between the Builder, Naval Authority and LR and is to address LR Rule requirements.

4.5.2 The trials are to be conducted at agreed operating conditions and are to demonstrate the functional capability of engineering systems.

4.5.3 Emergency trips and emergency operating modes are to be demonstrated.

4.5.4 Where a FMEA report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:
(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of essential services.

4.5.5 The trials records are to be documented with sufficient detail to ascertain that the specified functional requirements of engineering systems have been satisfied. The records are to be available to enable any future trials to verify any significant degradation after in-service operation.

4.6 Through life operation principles

4.6.1 Engineering systems and equipment are to be operated and maintained such that the provisions of classification are achieved throughout the life of the vessel.

4.6.2 Modifications that may affect the provisions of classification are to be approved by LR.

4.6.3 Verification and validation activities are to be employed throughout the life of the ship to ensure compliance with the provisions of classification.

4.6.4 Suitable documentation is to be available to ensure that the provisions of classification can be performed effectively.

4.6.5 Persons with responsibilities for activities that may affect the provisions of classification are to be competent/qualified to discharge those responsibilities.

4.6.6 The configuration of the vessel shall be identified and controlled throughout its life.

4.6.7 Operating and maintenance manuals for all engineering systems are to be provided on board and are to include the following information:
(a) Particulars of engineering systems.
(b) Operating instructions for all engineering systems.
(c) Maintenance instructions for engineering systems and equipment.

■ *Section 5*
Acceptance criteria

5.1 Acceptance

5.1.1 The acceptance process ensures conformity of engineering systems to the provisions of Classification by assessing such systems against LR Rules and Regulations or their equivalent, and specified Standards or Codes.

5.1.2 The assessment process of engineering systems extends over the full lifecycle of the systems.

5.1.3 The assessment requirements applicable to engineering systems are dependent upon the system designation and are detailed in Table 1.5.1.

5.2 Military systems guidance

5.2.1 Where military systems are to be installed in accordance with Naval Authority requirements and guidance within these Rules, the assessment process will be in accordance with the requirements for systems within the Ancillary category in Table 1.5.1 and as detailed in 5.2.2 to 5.2.4.

5.2.2 LR design review will assess the proposed arrangements for compliance with Naval Authority requirements, the design statement, Rule guidance and any applicable Rule requirement where the system interfaces with the provisions of classification.

5.2.3 Survey during installation will validate that the system has been installed with the particulars submitted.

5.2.4 Survey during service will be subject to agreement between LR and the Owner/Operator for individual installations.

Table 1.5.1 Assessment process for engineering systems

PROCESS \ SYSTEM	MOBILITY CATEGORY	SHIP TYPE CATEGORY	ANCILLARY CATEGORY
DESIGN REVIEW	• Plans of all systems are to be appraised by LR • Procedure for component approval is to be agreed between the producer and LR • Procedure for component approval is to be agreed	• Plans to be appraised by LR when required by the Rules and where additional optional Class notation(s) are requested by Owners	• Plans of system arrangements are to be reviewed by LR • Design review by LR where required by the Rules
CONSTRUCTION	• All major components and items of equipment are to be constructed under survey in accordance with plans approved by LR and Rule requirements	• To be constructed under survey when required by the Rules or Regulations	• No requirements unless required by the Rules
INSTALLATION	• To be installed under survey in accordance with plans approved by LR and Rule requirements	• To be installed under survey in accordance with plans approved by LR and Rule requirements	• No requirements unless required by the Rules
TRIALS	• To be tested under specified load conditions	• To be tested under normal working conditions	• Running test of systems under working conditions
IN SERVICE	• Subject to survey by the Rules or Regulations	• Subject to survey where required by the Rules or Regulations or requested by Owners or Naval Authority	• No requirements unless required
MODIFICATIONS	• Details of any modifications are to be approved by LR • Construction, installation and trials are to be carried out under survey	• Details of any modifications are to be approved and construction, installation and trials are to be carried out under survey when required by the Rules or Class notation	• Details of any modifications are to be recorded to enable review by LR Surveyors
DE-COMMISSIONING	• Details are to be submitted for consideration	• Details are to be submitted for information	• Details are to be recorded

■ *Section 6* Routes to conformance

6.1 Design and construction

6.1.1 Plans/procedures as required by the Rules are to be approved by LR.

6.1.2 In general, LR acceptance of engineering systems or equipment is by the producer demonstrating compliance with the LR Type Approval system (*see* Section 9). Alternatively, approval of individual systems or equipment may be carried out on the basis of Design Appraisal combined with testing or acceptable service experience.

6.1.3 Conformance with the Construction Requirements of systems or equipment is to be demonstrated through compliance with Quality Assurance Scheme for Machinery or survey of individual items at the manufacturer's works.

6.1.4 Materials are to have certificates acceptable to LR (*see* Section 7).

6.1.5 Testing of components, equipment and systems after manufacture is to comply with the Rules and any applicable standards and codes.

6.2 Machinery to be constructed under survey

6.2.1 All major units of equipment within the Mobility category and where specifically required within the Ship Type category and Ancillary category, are to be individually surveyed at the manufacturer's works or meet the requirements of the Quality Assurance Scheme for Machinery. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion prime movers (oil engines, gas turbines and steam turbines) including their associated gearing, flexible couplings and turbochargers as applicable.
- Boilers supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, including superheaters, economizers, desuperheaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea.

- Steering machinery.
- Athwartship thrust units, their prime movers and control mechanisms.
- All pumps necessary for the operation of main propulsion and essential machinery, e.g. boiler feed, cooling water circulating, condensate extraction, oil fuel and lubricating oil pumps.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g. air, water and lubricating oil coolers, oil fuel and feed water heaters, de-aerators and condensers, evaporators and distiller units.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in Pt 8, Ch 2.
- All pumps essential for safety of the ship, e.g. fire, bilge and ballast pumps, exceeding 7 bar.
- Alarm and control equipment as detailed in Pt 9, Ch 1.
- Electrical equipment and electrical propelling machinery as detailed in Pt 10, Ch 1.

6.3 Survey for classification

6.3.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power and any other specified working conditions. Any defects, etc., are to be indicated as early as possible. On completion, a certificate will be issued and an appropriate notation will be assigned in accordance with the Regulations.

6.4 Alternative system of inspection

6.4.1 Where items of machinery are manufactured as individual or series produced units, consideration will be given to the adoption of a survey procedure based on quality assurance concepts utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

6.4.2 In order to obtain approval, the requirements of Section 8 are to be complied with.

6.5 Installation

6.5.1 Where required by the assessment process in Table 1.5.1, engineering systems are to be installed under survey in accordance with approved plans and relevant LR Design Appraisal documentation and LR Rules.

6.5.2 Documentation required during installation is to be available for inspection by the Owners and LR Surveyors. Such documentation may include:

- Design Appraisal Documents.
- Type Test Certificates.
- Materials Certificates.
- Type Approval Certificates.
- Quality Assurance Certificates.
- Certificates of Construction.

6.6 Trials

6.6.1 Engineering systems are to be tested on completion of installation to demonstrate functionality and suitability for purpose in accordance with LR Rules.

6.6.2 Records of trials and testing required by the assessment process in Table 1.5.1 are to be maintained on board the ship.

6.7 In service survey

6.7.1 Where required by the assessment process in Table 1.5.1 and in the Regulations, engineering systems are to be surveyed at intervals defined in the Regulations.

6.7.2 Records of in service survey where carried out by the Marine Engineering Officer are to be maintained on board the ship, as defined in the Regulations.

6.8 Modifications

6.8.1 Details of modifications to engineering systems or equipment are, as required by Table 1.5.1 to be submitted to LR for consideration.

6.8.2 Records of all modifications to in-service engineering systems that may alter the provisions of classification, are to be maintained on board the ship.

6.9 De-commissioning

6.9.1 Details of de-commissioning of engineering systems, as required by Table 1.5.1, are to be submitted to LR for consideration.

6.9.2 Records of de-commissioning of all equipment and systems that may alter the provisions of classification are to be maintained on board the ship.

6.10 Upkeep by exchange

6.10.1 Where propulsion and auxiliary machinery is maintained using an ‘upkeep by exchange’ policy, details of the system are to be submitted to LR for approval.

6.10.2 Where an ‘upkeep by exchange’ system has been approved, plans of individual replacement units are not required to be submitted provided there have been no changes since the original approval. The manufacture and testing of the replacement units is to be in accordance with the relevant Rule requirements.

6.10.3 Records of each 'upkeep by exchange' are to be maintained on board the ship and LR is to witness running tests on load after each exchange. A record history is to be maintained for each exchange unit in the form of a log book.

■ *Section 7* Certification of materials

7.1 Materials of construction

7.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to Vol 1, Part 2, *Rules for the Manufacture, Testing and Certification of Materials*. Details of all materials included and not included in Vol 1, Part 2 are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

■ *Section 8* Quality assurance scheme for machinery

8.1 General

8.1.1 This certification scheme is applicable to both individual and series produced items manufactured under closely controlled conditions and will be restricted to works where the employment of quality control procedures is well established. LR will have to be satisfied that the practices employed will ensure that the quality of finished products is to standards which would be demanded when using traditional survey techniques.

8.1.2 The Committee will consider proposed designs for compliance with LR's Rules or other appropriate requirements and the extent to which the manufacturing processes and control procedure ensure conformity of the product to the design. A comprehensive survey will be made by the Surveyors of the actual operation of the quality control programme and of the adequacy and competence of the staff to implement it.

8.1.3 The procedures and practices of manufacturers which have been granted approval will be kept under review.

8.1.4 Approval by another organization will not be accepted as sufficient evidence that a manufacturer's arrangements comply with LR's requirements.

8.2 Requirements for approval

8.2.1 **Facilities**. The manufacturer is required to have adequate equipment and facilities for those operations appropriate to the level of design, development and manufacture being undertaken.

8.2.2 **Experience**. The manufacturer shall demonstrate that the firm has experience consistent with the technology and complexity of the product type for which approval is sought and that the firm's products have been of a consistently high standard.

8.2.3 **Quality policy**. The manufacturer shall define management policies and objectives for quality and ensure that these policies and objectives are implemented and maintained throughout all phases of the work.

8.2.4 **Quality system documentation**. The manufacturer shall establish and maintain a documented quality system capable of ensuring that material or services conform to the specified requirements, including the requirements of this Section.

8.2.5 **Management representative**. The manufacturer shall appoint a management representative preferably independent of other functions, who shall have defined authority and responsibilities for the implementation and maintenance of the quality system.

8.2.6 **Responsibility and authority**. The responsibilities and authorities of senior personnel within the quality system shall be clearly documented.

8.2.7 **Internal audit**. The manufacturer shall conduct internal audits to ensure continued adherence to the system. An audit programme shall be established with audit frequencies scheduled on the basis of the status and importance of the activity and adjusted on the basis of previous results.

8.2.8 **Management review**. The quality system established in accordance with the requirements of this Section shall be systematically reviewed at appropriate intervals by the manufacturer to ensure its continued effectiveness. Records of such management reviews shall be maintained and be made available to the Surveyors.

8.2.9 **Contract review**. The manufacturer shall establish and implement procedures for conducting a contract review prior to and after acceptance to ensure that:

(a) The requirements of the contract are adequately defined and documented.
(b) Any requirements differing from those specified in the original enquiry/tender are resolved.
(c) The manufacturer has the capability to meet and verify compliance to the specified requirements.

8.2.10 **Work instruction**. The manufacturer shall establish and maintain clear and complete written work instructions that prescribe the communication of specified requirements and the performance of work in design, development and manufacture which would be adversely affected by lack of such instructions.

8.2.11 **Documentation and change control**. The manufacturer shall establish and maintain control of all documentation that relates to the requirements of this scheme. This control shall ensure that:

(a) Documents are reviewed and approved for adequacy by authorized personnel prior to use, are uniquely identified and include indication of approval and revision status.
(b) All changes to documentation are in writing and are processed in a manner that will ensure their availability at the appropriate location and preclude the use of non-applicable documents.
(c) Provision is made for the prompt removal of obsolete documentation from all points of issue or use.
(d) Documents shall be re-issued after a practical number of changes have been issued.

8.2.12 **Records**. The manufacturer shall develop and maintain a system for collection, use and storage of quality records. The period of retention of such records shall be established in writing and shall be subject to agreement by LR.

8.2.13 **Design**. The manufacturer shall establish and maintain a design control system appropriate to the level of design being undertaken. Documented design procedures shall be established which:

(a) Identify the design practices of the manufacturer's organization including departmental instructions to ensure the orderly and controlled preparation of design and subsequent verification.
(b) Make provision for the identification, documentation and appropriate approval of all design change and modifications.
(c) Prescribe methods for resolving incomplete, ambiguous or conflicting requirements.
(d) Identify design inputs such as sources of data, preferred standard parts or materials and design information and provide procedures for their selection and review by the manufacturer for adequacy.

8.2.14 **Purchasing**. The manufacturer shall ensure that purchased material and services conform to specified requirements.

8.2.15 **Selection and approval of sub-contractors and suppliers**. The manufacturer shall establish and maintain records of acceptable suppliers and sub-contractors. The selection of such sources and the type and extent of control exercised shall be appropriate to the type of product or service and the suppliers' or sub-contractors' previously demonstrated capability and performance. Documented procedures for approval of new suppliers shall be established and records of vendor assessments (where carried out) shall be maintained and made available to the Surveyors upon request.

8.2.16 **Purchasing data**. Each purchasing document should contain a clear description of the material or service ordered including as applicable, the following:

(a) The type, class, grade, or other precise identification.
(b) The title or other positive identification and applicable issue of specifications, drawings, process requirements, inspection instructions and other relevant data.

8.2.17 **Verification of purchased material and services**. The manufacturer shall ensure that the Surveyors are afforded the right to verify at source or upon receipt that purchased material and services conform to specified requirements. Verification by the Surveyors shall not relieve the manufacturer of his responsibility to provide acceptable material nor shall it preclude subsequent rejection.

8.2.18 **Product identification**. The manufacturer shall establish and maintain a system for identification of the product to relevant drawings, specifications or other documents during all stages of production, delivery and installation.

8.2.19 **Manufacturing control**. The manufacturer shall ensure that those operations which directly affect quality are carried out under controlled conditions. These shall include the following:

(a) Written work instructions wherever the absence of such instructions could adversely affect compliance with specified requirements. These should define the method of monitoring and control of product characteristics.
(b) Established criteria for workmanship through written standards or representative samples.

8.2.20 **Special processes**. Those processes where effectiveness cannot be verified by subsequent inspection and test of the product shall be subjected to continuous monitoring in accordance with documented procedures in addition to the requirements specified in 8.2.19.

8.2.21 **Receiving inspection**. The manufacturer shall ensure that all incoming material shall not be used or processed until it has been inspected or otherwise verified as conforming to specified requirements. In establishing the amount and nature of receiving inspection, consideration shall be given to the control exercised by the supplier and documented evidence of quality conformance supplied.

8.2.22 **In-process inspection**. The manufacturer shall:

(a) perform inspection during manufacture on all characteristics that cannot be inspected at a later stage;
(b) inspect test and identify products in accordance with specified requirements;
(c) establish product conformance to specified requirements by use of process monitoring and control methods where appropriate;
(d) hold products until the required inspections and tests are completed and verified; and
(e) clearly identify non-conforming products to prevent unauthorized use, shipment, or mixing with conforming material.

8.2.23 **Final inspection**. The manufacturer shall perform all inspections and tests on the finished product necessary to complete the evidence of conformance to the specified requirements. The procedures for final inspection and test shall ensure that:

(a) all activities defined in the specification, quality plan or other documented procedure have been completed;
(b) all inspections and tests that should have been conducted at earlier stages have been completed and that the data is acceptable; and

(c) no product shall be dispatched until all the activities defined in the specifications, quality plan or other documented procedure have been completed, unless products have been released with the permission of the Surveyors.

8.2.24 **Inspection equipment**. The manufacturer shall be responsible for providing, controlling, calibrating and maintaining the inspection, measuring and test equipment necessary to demonstrate the conformance of material and services to the specified requirements or used as part of the manufacturing control system required by 8.2.19 and 8.2.20.

8.2.25 **Inspection and test status**. The manufacturer shall establish and maintain a system for the identification of inspection status of all material, components and assemblies by suitable means which distinguish between conforming, non-conforming and uninspected items. The relevant inspection and test procedures and records shall identify the authority responsible for the release of conforming products.

8.2.26 **Control of non-conforming material**. The manufacturer shall establish and maintain procedures to ensure that material that does not conform to the specified requirements is controlled to prevent inadvertent use, mixing or shipment. Repair, rework or concessions on non-conforming material and reinspection shall be in accordance with documented procedures. Records clearly identifying the material, the nature and extent of non-conformance and the disposition shall be maintained.

8.2.27 **Sampling procedures**. Where sampling techniques are used by the manufacturer to verify the acceptability of groups of products, the procedures adopted shall be in accordance with the specified requirements or shall be subject to agreement by the Surveyors.

8.2.28 **Corrective action**. The manufacturer shall establish and maintain documented procedures for the review of non-conformances and their disposition. These should provide for:

(a) monitoring of process and work operations and analysis of records to detect and eliminate potential causes of non-conforming material;
(b) continuing analysis of concessions granted and material scrapped or reworked to determine causes and the corrective action required;
(c) an analysis of customer complaints;
(d) the initiation of appropriate action with suppliers or sub-contractors with regard to receipt of non-conforming material; and
(e) an assurance that corrective actions are effective.

8.2.29 **Purchaser supplied material**. The manufacturer shall establish and maintain documented procedures for the control of purchaser supplied material.

8.2.30 **Handling, storage, and delivery**. The manufacturer shall establish and maintain a system for the identification preservation, segregation and handling of all material from the time of receipt through the entire production process. The system shall include methods of handling that prevent abuse, misuse, damage or deterioration. Secure storage areas or rooms shall be provided to isolate and protect material pending use. To detect deterioration, at an early stage, the condition of material shall be periodically assessed. The manufacturer shall arrange for the protection of the quality of his product during transit. The manufacturer shall ensure, in so far as it is practicable, the safe arrival and ready identification of the product at destination.

8.2.31 **Training**. The manufacturer is to follow a policy for recruitment and training which provides an adequate labour force with such skills as are required for each type of work operation. Appropriate records shall be maintained to demonstrate that all personnel performing process control, special processes inspection and test or quality system maintenance activities have appropriate experience or training.

8.3 Arrangements for acceptance and certification of purchased material

8.3.1 The manufacturer shall establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of materials and components at the supplier's plant. The manufacturer's system for control of such purchased material may be based on one of the following alternatives subject to the approval of the Committee:

(a) Product certification by LR's Surveyors at the supplier's works in accordance with the requirements of Vol 1, Part 2.
(b) Agreed Inspection Procedures at the manufacturer's plant combined with documentary evidence of vendor assessments, vendor rating records and annual surveillance visits to the suppliers.
(c) Recognition of quality Agreements between the manufacturer and his suppliers which shall provide for initial vendor assessments and regular surveillance visits (a minimum of four per year). The quality agreement must identify the individual in the supplier's plant who is charged with the responsibility for release of materials or components and the procedures to be adopted.

8.3.2 The alternatives proposed in 8.3.1(b) and (c) are not acceptable to LR for the following items:

(a) Engine components for which testing is a Rule requirement, and
  (i) the cylinder bore is equal to or exceeds 250 mm, or
  (ii) which are made by open forging techniques.

(b) Cast crankshafts where the journal diameter exceeds 85 mm.

Where the manufacturer's system for control of purchased material is based upon 8.3.1(b) or (c) the Surveyors shall also make surveillance visits to the supplier's works at the minimum specified intervals. The manufacturer shall also make available to the Surveyors documentary evidence of the operation of Quality Agreements or Agreed Inspection Procedures where applicable.

8.4 Information required for approval

8.4.1 Manufacturers applying for approval under this scheme are to submit the following information:

(a) A description of the products for which certification is required including, where applicable, model or type number.
(b) Applicable plans and details of material used.
(c) An outline description of all important manufacturing plant and equipment.
(d) A summary of equipment used for measuring and testing during manufacture and completion.
(e) The Quality Manual.
(f) A typical production flow chart and quality plan covering all stages from ordering of materials to delivery of the finished product.
(g) The system used for the identification of raw materials, semi-finished and finished products.
(h) The number and qualifications of all staff engaged in testing, inspection and quality control duties.
(j) A list of suppliers of components and manufacturers, proposed procedures to ensure compliance with LR's requirements for certification, of materials and components at the supplier's plant.

8.5 Assessment of works

8.5.1 After receipt and appraisal of the information requested in 8.4 an inspection of the works is to be carried out by the Surveyors to examine in detail all aspects of production, and in particular the arrangements for quality control.

8.5.2 The Surveyors will not specify in detail acceptable quality control procedures, but will consider the arrangements proposed by the works in relation to the manufacturing processes and products.

8.5.3 In the event of procedures being considered inadequate, the Surveyors will advise the manufacturer how such procedures are to be revised in order to be acceptable to LR.

8.5.4 Gauging, measuring and testing devices are to be made available to the Surveyors, and where appropriate, personnel for the operation of such devices.

8.6 Approval of works

8.6.1 If the initial assessment of the works confirms that the manufacturing and quality control procedures are satisfactory, the committee will issue to the manufacturer a Quality Assurance Approval Certificate which will include details of the products for which approval has been given. This Certificate will be valid for three years with renewal subject to satisfactory performance and to a satisfactory triennial re-assessment.

8.6.2 An extension of approval in respect of product type may be given at the discretion of the Committee without any additional survey of the works.

8.6.3 LR will publish a list of manufacturers whose works have been approved.

8.7 Maintenance of approval

8.7.1 The arrangements authorized at each works are to be kept under review by the Surveyors in order to ensure that the approved procedures for manufacture and quality control are being maintained in a satisfactory manner. This is to be carried out by:

(a) regular and systematic surveillance;
(b) intermediate audits at intervals of six months;
(c) triennial re-assessment of the entire quality system.

8.7.2 For the purpose of regular and systematic surveillance the Surveyors are to visit the works at intervals determined by the type of product and the rate of production. The Surveyors are to advise a senior member of the quality control department in regard to any matter with which they are not satisfied.

8.7.3 When minor deficiencies in the approved procedures are disclosed during the systematic surveillance the Surveyors may, at their discretion, apply more intensive supervision, including the direct inspection of products.

8.7.4 Any noteworthy departures from the approved plans of specifications are to be reported to the Surveyors and their written approval obtained prior to dispatch of the item.

8.7.5 Minor alterations in the approved procedures may be permitted provided that the Surveyors are advised and that their prior concurrence obtained.

8.7.6 In addition to the regular visits by the Surveyors, an intermediate audit is to be carried out every six months. This will normally be carried out by Surveyors other than those regularly in attendance at the works. This audit is to consist of an examination of part of the manufacturer's quality system. An audit plan will be established indicating those areas of the quality system which will be examined during every intermediate audit and the frequency of examination of other areas such that all areas are subject to audit before re-assessment is due.

8.7.7 The manufacturer's entire quality system shall be subject to re-assessment at three-yearly intervals. This shall be conducted by Surveyors nominated by Headquarters.

8.8 Suspension or withdrawal of approval

8.8.1 When the Surveyors have drawn attention to significant faults or deficiencies in the manufacturing or quality control procedures and these have not been rectified, approval of the works will be suspended. In these circumstances the manufacturer will be notified in writing of the Committee's reasons for the suspension of approval.

8.8.2 When approval has been suspended and the manufacturer does not effect corrective measures within a reasonable time, the Committee will withdraw the Quality Assurance Approval Certificate.

8.9 Identification of products

8.9.1 In addition to the normal marking by the manufacturer, all certified products are to be hard stamped on a principal component with a suitable identification, LR's brand and the number of the approved works.

8.9.2 After issue of the Quality Assurance Approval Certificate, products may be dispatched with certificates signed on behalf of the manufacturer by an authorized senior member of the quality control department or by an authorized deputy. These certificates are to be countersigned by the Surveyor to certify that the approved arrangements are being kept under review by regular and systematic auditing of the manufacturer's quality system.

8.9.3 The following declarations are to be included on each certificate:

(a) 'This is to certify that the items described above have been constructed and tested with satisfactory results in accordance with the Rules of Lloyd's Register of Shipping.
Signed...
Manager of QC Department.'

(b) 'This certificate is issued by the manufacturer in accordance with the arrangements authorized by Lloyd's Register in Quality Assurance Approval Certificate No. QA.M.................................. I certify that these arrangements are being kept under review by regular and systematic auditing of the approved manufacturing and quality control procedures.
Signed...
Surveyor to Lloyd's Register'.

8.9.4 In the event of noteworthy departures from the approved plan or specification being accepted, a standard 'Concession' form is to be completed and signed by the following authorized persons: the Design Manager, the Quality Control Manager or their deputies. In all cases, where strength or functioning may be affected, the form is to be submitted to the Surveyors for approval and endorsement.

■ *Section 9* Type approval system (for information)

9.1 General

9.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

9.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing prove its suitability for its intended operation. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the manufacturer testifies that each item delivered is in conformity with that which has been type tested.

9.1.3 Details of LR's Type Approval System are contained in the following LR publications:

- Procedure TA96.
- Test Specification 1: Electrical and Control Engineering Products which are Environmentally Tested.
- Test Specification 2: Piping System Components.
- Test Specification 3: Electrical products that do not require Environmental Testing.
- Test Specification 4: Internal Combustion Engines.
- Test Specification GT98: Gas Turbines.

9.2 Approval criteria

9.2.1 LR Type Approval does not preclude inspection and survey procedures required by these Rules for equipment to be installed in naval ships classed or intended to be classed with LR.

9.2.2 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of these Rules are fulfilled.

9.2.3 Where equipment or components have been type approved in accordance with procedures other than LR's, details of the product, certification and testing are to be submitted for consideration.

Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to the design, construction, installation and testing of Mobility, Ship Type, and Ancillary category engineering systems for classed naval ships and covers:

- Main propulsion systems.
- Steering and manoeuvring systems.
- Electrical power systems.
- Essential auxiliary machinery systems.
- Other engineering systems necessary for the watertight and weathertight integrity and functioning of ship type features.
- Together with their equipment, pressure plant, piping systems, control engineering and electrical engineering systems.

1.1.2 Detailed and additional requirements for control engineering and electrical engineering systems are contained Part 9 and Part 10 respectively.

■ *Section 2* General provisions

2.1 Provisions

2.1.1 The units and formulae used in the Rules are in SI Units.

2.1.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

2.1.3 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed or equivalent design and performance criteria.

2.1.4 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

2.1.5 Provision shall be made to facilitate cleaning, inspection and maintenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

2.1.6 Where it is proposed to depart from the requirements of the Rules, full details are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') to enable consideration to be given to the circumstances of any special case.

2.1.7 Any novelty in the design and/or construction of machinery, boilers, pressure vessels or engineering equipment is to be advised to LR.

■ *Section 3* Particulars to be submitted

3.1 Submission of information

3.1.1 At least three copies of plans, information, and specifications as listed are to be submitted before commencement of manufacture.

3.2 Plans

3.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

3.2.2 Individual Chapters list plans to be submitted for specific machinery and electrical systems or components. Also required are the following arrangement plans where applicable:

(a) Plans showing the arrangement of machinery spaces indicating the location of machinery and equipment together with means of access and ventilation.
(b) Plans showing the maintenance envelope and removal routes of machinery and equipment where routine removal for maintenance is proposed.

3.2.3 Where machinery system components have been approved under LR's Type Approval System or Quality Assurance Scheme for Machinery for the proposed design conditions or service, plans of the component are not required to be submitted. Full details of the components and the existing LR approval are to be submitted.

3.2.4 Where operating requirements relating to the design, construction, testing and installation of machinery and engineering systems have been defined within the scope of Section 4, evidence of capability and details of previous or proposed testing to demonstrate capability are to be submitted.

3.2.5 Where an oil or liquefied petroleum gas fired galley is proposed, details of the oil and gas storage and distribution arrangements together with ventilation arrangements and safety shut-down and alarms are to be submitted.

3.3 Calculations and specifications

3.3.1 Relevant data covering paragraphs 3.3.2 to 3.3.9 as applicable is to be submitted.

3.3.2 **Service Profile**. The machinery power/speed operational envelope, grade(s) of fuel and any short term high power operation.

3.3.3 **Classification rating**. The following operational parameters, using the design conditions for the intended Class Notation(s):

Total barometric pressure, bar.
Temperature of engine room, or suction air, °C.
Relative humidity, per cent.
Maximum/minimum temperatures of sea-water, or charge air coolant inlet, °C.

See 4.4.1 for ambient reference conditions.

3.3.4 **Short term high power operation**. Where the propulsion machinery is being considered for short term high power operation full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.
(b) Excessive overload may require the interval between surveys to be reduced.
(c) Plans showing the arrangement of resiliently mounted machinery which are to indicate the number, position, type and design of the mounts.
(d) Machinery is to be maintained in accordance with manufacturer's requirements.

3.3.5 **Damper and Flexible Coupling characteristics**. Documentary evidence that the characteristics have been verified.

3.3.6 **Machinery Fastening**.

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the ship motions and accelerations to be expected during service.
(b) Calculations to demonstrate that mountings of large masses such as main engines, auxiliary engines and electrical equipment can withstand the design collision acceleration without fracturing.
(c) Plans showing the arrangement of resiliently mounted machinery which are to indicate the number, position, type and design of mounts.
(d) Natural frequency calculation of resilient mounted machinery.
(e) Plans showing the arrangement of resin chocks for machinery requiring accurate alignment with the following information:
    (i) Resin type.
    (ii) The effective area and minimum thickness of the chocks.
    (iii) The total deadweight loading of machinery.
    (iv) The thrust load, where applicable, that will be applied to the chocked item.
    (v) The loading to be applied to the holding-down bolts.
    (vi) The material of the holding-down bolts.
    (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

See 5.3, 5.4 and 5.5 for requirements.

3.3.7 **Manuals**. The operation and maintenance manuals. For class notations covering propulsion and steering machinery redundancy and dynamic positioning, *see* Volume 3.

3.3.8 **Failure Mode and Effect Analysis**. A FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems supporting propulsion, steering or other essential services.
(b) Steering systems.
(c) Electrical generation and distribution systems supporting (a) and (b).

This requirement is in addition to the requirements for class notations covering propulsion and steering machinery redundancy and dynamic positioning (*see* Volume 3), and Ship Type piping systems (*see* Pt 7, Ch 5 of this Volume). *See* Section 17 for FMEA format requirements.

3.3.9 **Fatigue Strength Analysis**. Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

3.3.10 **NBC Protection arrangements**. Where the Naval Authority has defined NBC Protection requirements, a design statement together with plans and particulars are to be submitted for information. *See* 4.11 for NBC Protection guidance.

3.3.11 **Shock resistance arrangements**. Where the Naval Authority has defined shock capability requirements for machinery, engineering systems and equipment, a design statement together with plans and particulars are to be submitted for information. *See* 4.10 for shock resistance guidance.

3.3.12 **Underwater signature arrangements**. Where the Naval Authority has defined underwater signature requirements for the ship and propulsion system, a design statement together with plans and particulars are to be submitted for information. *See* 4.9 for underwater signature guidance.

3.3.13 **Electromagnetic compatibility.** A test plan in accordance with Clause 5 of IEC 60533 for electromagnetic compatibility is to be submitted for information. *See* 4.12 for EMC requirements.

3.3.14 **Fin stabilisers.** Where fin stabiliser systems are fitted to a naval ship to reduce the rolling motion of the ship to a stated limit, the following details are to be submitted.

(a) A design statement that details the stabiliser performance in terms of a specified roll angle that is not to be exceeded by more than a stated percentage of rolls in a specified wave environment (see Vol 1, Pt 5, Ch 2,2.3) at a specified ship speed and heading. This statement is to be agreed between the Designer and Owner/Operator and recognize the requirements for ship-based operations, such as flight operations and replenishment at sea (RAS) systems, in terms of sea-keeping and platform heel/trim conditions, and the requirements of Section 4 regarding operating conditions as applicable.
(b) Plans of all load bearing, torque transmitting components and hydraulic pressure retaining parts of the fin stabiliser system together with proposed rated torque, all relief valve settings and scantlings.
(c) Schematic plans of the hydraulic system(s), together with pipe material, relief valves and working pressures.
(d) Details of safety and control and electrical engineering arrangements.
(e) Material specifications for components identified in (b).
(f) Details of proposed testing and sea trials.

■ *Section 4* Operating conditions

4.1 Availability for operation

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board ship, without external aid, so that operating conditions can be maintained.

4.1.2 Installed machinery is to be capable of operating at defined power ratings with a range of fuels specified by the manufacturer and agreed by the Owner/Operator.

4.1.3 Smoke and emission levels from machinery exhaust systems are to be in accordance with those specified by the manufacturer and agreed by the Owner/Operator over the full operating range.

4.2 Oil fuel

4.2.1 The flash point (closed cup test) of oil fuel for use in naval ships classed for unrestricted service is, in general, to be not less than 60ºC.

4.2.2 The use of fuel having a lower flash point than specified in 4.2.1, as applicable, may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved. *See* Pt 7, Ch 4.

4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient reference conditions

4.4.1 The rating for classification purposes of main and essential auxiliary machinery intended for installation in naval sea-going ships to be classed for unrestricted (geographical) service is to be based on:

A total barometric pressure of 1000 mb.
An engine room ambient temperature or suction air temperature of 45ºC.
A relative humidity of 60 per cent.
Sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32ºC.

4.4.2 In the case of a naval ship to be classed for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service.

4.5 Inclination of ship

4.5.1 Main and essential auxiliary machinery, electrical and emergency equipment is to operate satisfactorily under the conditions as shown in Table 2.4.1.

4.5.2 The arrangements for lubricating bearings and for draining crankcase and oil sumps of main and auxiliary engines, gearcases, electric generators, motors and other running machinery are to be designed so that they will remain efficient with the ship inclined under the conditions shown in Table 2.4.1.

4.5.3 Any proposal to deviate from the angles given in Table 2.4.1 will be specially considered taking into account the type, size and service conditions of the ship.

4.5.4 The dynamic angles of inclination in Table 2.4.1 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

4.6 Power conditions for generator sets

4.6.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines and gas turbines, of developing for a short period (15 minutes) an overload power of not less than 10 per cent.

4.6.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the requirements in 4.6.1, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in 4.4.1. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With oil engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

4.7 Astern power

4.7.1 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

4.7.2 Astern turbines are to be capable of maintaining in free route astern 70 per cent of the ahead revolutions, corresponding to the maximum propulsion shaft power for which the machinery is to be classed, for a period of at least 30 minutes without undue heating of the ahead turbines and condensers.

4.8 Military requirements

4.8.1 The Naval Authority is responsible for defining the military requirements relating to the design, construction, testing and installation of machinery and engineering systems.

Table 2.4.1 Inclinations

Engineering installations and equipment	Angle of inclination, degrees (*see* Note 1)			
	Athwartship		Fore-and-aft	
	Static (Heel)	Dynamic (Roll)	Static (Trim)	Dynamic (Pitch)
Main and auxiliary machinery essential to the propulsion and safety of the ship including essential electrical equipment	15	±22,5	5 (*see* Note 2)	±7,5
Emergency machinery and equipment including electrical equipment. Switchgear, electrical and electronic appliances (*see* Note 3) and remote control systems	22,5 (*see* Note 4)	±22,5	10	±10

NOTES
1. Athwartships and fore-and-aft inclination may occur simultaneously.
2. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as 500/*L* degrees where *L* = length of ship, in metres.
3. Up to an angle of inclination of 45 degrees no undesired switching operations or operational changes may occur.
4. A static damaged condition up to a maximum of 30 degrees may be required by the Naval Authority.

4.8.2 The following aspects are to be considered for machinery and engineering systems where military requirements are defined:

- Acoustic tiling and other noise reduction techniques.
- Action damage repairs.
- Alternative/backup supplies.
- Chocking and securing of machinery.
- Design and installation of machinery to withstand shock.
- Electromagnetic compatibility.
- Electromagnetic hazards to personnel.
- Electromagnetic hazards to fuel storage.
- Electromagnetic hazards to ammunition storage.
- Equipment in magazine spaces.
- IR emission.
- Laser hazards.
- Magnetic restrictions.
- Manoeuvring capabilities.
- NBCD capability.
- Noise and vibration for machinery derived noise and vibration signatures.
- Operation of equipment at high ambient temperatures associated with closedown situations.
- Operation of machinery under excessive list and trim conditions.
- Operation of machinery under partial flooding or damage conditions.
- Radar cross-section.
- Reversionary modes of operation.
- Ruggedness of installation and equipment.
- Shutdown and isolation of HVAC systems.
- Smoke clearance requirements.

The foregoing list is not exhaustive and additional aspects may be included by the Naval Authority.

4.8.3 Guidance on design and installation of machinery and engineering systems covering military requirements where they interface with the provisions of classification may be sought from LR for particular installations.

4.8.4 Where a military requirement for disabling automatic control, protection or safety functions for machinery and engineering systems has been defined by the Naval Authority, the consequences of using the disabling arrangements are to be established and included in the operations procedures and orders provided on board the ship. Details of any disabling arrangements are to be submitted to LR for consideration in each instance.

4.8.5 Where military mission requirements specify immediate availability of mobility and ship type category engineering systems from cold start conditions, the equipment and arrangements of sub-systems such as lubrication and cooling are to be suitable for operation at a defined level of capability and functionality at stated temperatures.

4.8.6 Systems provided to fulfil military requirements, e.g. weapons or combat systems, are to be arranged such that their operation or failure will not adversely affect the operation of Mobility, Ship Type or Ancillary category systems covered by theses Rules.

4.9 Guidance for underwater signature

4.9.1 Where military requirements for underwater signature have been identified by the Naval Authority, the guidance in 4.9.2 to 4.9.4 may be used to assist in achieving the requirements. The Naval Authority is responsible for defining the underwater signature and any requirements in addition to the guidance in this Section. The design statement is to include underwater signature levels for the ship and propulsion system, which should be agreed between the Designer and Owner/Operator, *see* 3.3.12.

4.9.2 Acceptance levels for propulsion and underwater signature are normally to be defined by the Naval Authority such that propulsive performance and the underwater signature may be determined.

4.9.3 The techniques that may be employed for control of underwater signature are outlined in Table 2.4.2 for guidance purposes.

Table 2.4.2 Control of underwater signature

Propeller noise	Low resistance hull at required quiet speed Attention to good inflow into propeller by integrated propeller/hull design Noise reduced low rpm propeller design
Propeller cavitation	Low resistance hull at required quiet speed Attention to good inflow into propeller by integrated propeller/hull design Attention to propeller design and detail Use of high tolerances in manufacture
Propeller induced vibration	Attention to propeller position relative to hull and the interaction between the hull and propeller Low resistance hull at required quiet speed Attention to good inflow into propeller by integrated hull/propeller design
Cavitation noise	Attention to good flow to appendages and appendage siting and alignment. Good appendage shapes

4.9.4 The techniques that may be employed for control of underwater signature are:

(a) All machinery should be assessed for its vibration characteristics.
(b) All constructional details connecting machinery to the hull should be assessed for their ability to transmit vibration into the water. If required, suitable vibration isolating machinery, pipe and cable mountings are to be used.
(c) The hull form should be optimised to give efficient performance at the noise quiet speed required in order to obtain the minimum propeller noise signature.
(d) The hull form should be fair and smooth to minimise resistance and flow noise.
(e) Underwater openings should be minimised and attention should be given to the noise characteristics of grilles and shutters.

(f) Attention should be given to the shape, position and alignment of underwater appendages in order to minimise local turbulence, but especially in the flow into the propellers.
(g) Propeller design should be carried out using appropriate noise reduction features.

4.10 Guidance for shock resistance

4.10.1 Where military requirements for machinery, engineering systems and equipment to have shock resistance have been identified by the Naval Authority, the guidance in 4.10.2 to 4.10.27 may be used to assist in achieving the requirements. The Naval Authority is responsible for defining the levels of shock resistance and any requirements in addition to the guidance in this Section. The design statement is to include shock capability levels for installed machinery, engineering systems and equipment which should be agreed between the Designer and Owner/Operator, *see* 3.3.11.

4.10.2 Design of shock resistance for installed machinery, engineering systems and equipment should address:
(a) Protection of the crew and embarked personnel.
(b) The capability of machinery, equipment and systems to operate after shock loading.
(c) The capability of securing arrangements to retain machinery and equipment captive after shock loading.
(d) The location of machinery/equipment and routing of essential electrical and piping systems to maintain services in the event of damage due to shock loading.

The application of design and installation of machinery systems for shock resistance is dependent on the Owner/ Operator requirements as shock capability may range from either full operational capability after repeated shock to that for retaining items captive to avoid injury to personnel. *See* 4.10.1 for design statement requirements.

4.10.3 A statement of how the specified shock levels have been accommodated within the design is to be agreed between the Shipbuilder and Owner/Operator and be included in the information required by 3.3.11. This may be by evidence of shock testing or calculations or a mixture of both, e.g. equipment previously tested to a particular shock acceleration for another application, may be specified on a vessel with a higher shock requirement on condition that it is resiliently mounted to attenuate the incoming shock to a level acceptable to the item. In this instance, past test results complemented by a mounting calculation for the more onerous condition would be appropriate.

4.10.4 Where military requirements to reduce the risks of shock damage to machinery, engineering systems and equipment have been identified by the Naval Authority, the good design practice guidance in 4.10.5 to 4.10.27 may be used to assist in achieving the requirements. The use of the guidance will not guarantee that an item of equipment will remain undamaged following shock but will provide confidence that most of the common design deficiencies are identified and avoided.

4.10.5 The use of non-ductile, brittle, low impact resistance, or high notch sensitivity materials, particularly grey cast iron and cast aluminium should be avoided. Materials used should, where possible, be capable of yielding by approximately 10 per cent before fracture. Whenever possible, the use of glass is to be avoided in machinery, engineering systems and equipment. Where substitution is not possible, toughened glass should be used.

4.10.6 The use of materials that will be exposed to temperatures below their ductile to brittle transition temperature should be avoided.

4.10.7 Stress concentrations in structural arrangements for machinery and equipment should be avoided and welds should be located away from high stress areas.

4.10.8 Items of equipment should be as light as possible whilst being compatible with the required strength and operational capability requirement.

4.10.9 Overhung and cantilevered components on machinery and equipment should be avoided where possible.

4.10.10 Where possible, direct support of connected items of equipment from two or more separate parts of the ship's structure, such as decks and bulkheads, should be avoided, since differences in response motions at these positions may cause damage. Gussets (or some other load spreading arrangement) should be used to spread loads to large surfaces and main structural members.

4.10.11 The arrangement of equipment attachment locations should be such that the height of the centre of gravity above the securing plane is small relative to the span of securing bolts; typically the height of the equipment centre of gravity should be less than one half of the distance between the outermost securing bolts.

4.10.12 To minimise relative movement between items of machinery and equipment that require a fixed relationship to each other, they should preferably be co-located on a common base.

4.10.13 The design of machinery trips and breakers should be such that shock movement cannot trigger them. Also, pivoted parts and link mechanisms, etc., should be balanced if possible.

4.10.14 Adequate clearances should be allowed between fixed and moving items, equipment and structure and pipes and structure. General clearances should be approximately 100 mm all round.

4.10.15 All fixing lugs should be closed eyes and not slots. Minimum clearance holes should be provided for bolts. General guidance; bolts up to 20 mm diameter, bolt diameter + 1 mm and for bolts larger than 20 mm, bolt diameter + 2 mm.

4.10.16 Bolted connections should be tightened to their specified torque limits consistent with the allowable stress in the bolt, typically 2/3 of the yield strength. Lock nuts that lock along the thread length should be used in preference to lock or star washers.

4.10.17 All connections to equipment that is resiliently mounted should be capable of accommodating the maximum displacements induced by shock. Resilient mounting of equipment onto equipment that is already resiliently mounted should be avoided.

4.10.18 Flexible hoses and bellows should have adequate deflection capability in all directions to accommodate relative displacements induced as a result of shock.

4.10.19 Removable items and racks, etc., should be positively secured when in situ with no reliance being made on friction grip or push fits.

4.10.20 Safety equipment (removable escape ladders, fire extinguishers etc) is to be secured with quick release arrangements.

4.10.21 Portable items should have secure stowage or attachments such that they do not become free following shock.

4.10.22 Electrical cables should be installed to accommodate relative movement under shock.

4.10.23 Where electrical system circuit breakers and fuses are rigidly fastened to the structure they should be of an approved shockproof design.

4.10.24 Electrical plug-in components such as printed circuits or relays should be positively secured in position. Retention by friction should be avoided.

4.10.25 Backlash in machinery and equipment system design should be kept to a minimum.

4.10.26 Piping runs should be supported in the region of valves and fittings and pipe connections should preferably be flanged and arranged as close to the elastic centre of the mounting system as possible.

4.10.27 Flexible mounts should not be degraded by the use of other rigid connections to equipment such as pipework.

4.11 Guidance for NBC protection, detection and monitoring

4.11.1 Where military requirements to operate under the threat of Nuclear, Biological and Chemical (NBC) warfare have been identified by the Naval Authority, the guidance in 4.11.2 to 4.11.14 may be used to assist in achieving the requirements. The Naval Authority is responsible for defining the levels of threat, operating periods and for specifying any NBC Protection requirements in addition to the guidance in this Section. The design statement for NBC Protection of the ship should be agreed between the Designer and Owner/Operator, *see* 3.3.10. For hull structure guidance, *see* Vol 1, Pt 4, Ch 1,7.

4.11.2 The prime objectives in the design of NBC Protection arrangements should address:

(a) Protection of the crew and embarked personnel.
(b) Capability of the ship to operate in close down conditions when engaged in military missions.

4.11.3 The ship will have a citadel in which the crew can shelter and in particular, ship operations can be managed for long term close down conditions. This citadel may be part or all of the ship. Larger citadels may be sub-divided into a number of smaller sub-citadels. The duration of operation with a citadel in use is to be defined in the design statement.

4.11.4 The citadel should be designed to provide an overpressure relative to external ambient conditions such that any leakage of air flows outward from spaces inside the ship. The system design for maintaining overpressure should recognize degradation of gas-tightness in the ship's structures during operational service and take into account known leakages for the purposes of establishing the required number of air filtration units.

4.11.5 Fresh air required for ventilation purposes should pass through an appropriate level of filtration before entering the citadel. Jalousies fitted at the intakes should be capable of controlling the ingestion of water, particulate and corrosive marine salts to limit degradation of filter units due to moisture carry over. The air filtration units should be capable of providing protection against nuclear, biological and chemical threats defined by the Naval Authority and should be capable of being cleaned and maintained in accordance with the manufacturer's recommendations. The air filtration systems should be capable of being operated from within the citadel. The maintenance arrangements for air filtration systems should ensure that there is minimum risk of introduction of contaminants into the citadel.

4.11.6 The number, capacity and arrangements of air filtration units should recognize the requirements for operational capability within the ship’s zoning policy and air supply requirements to any sub-citadels.

4.11.7 Access to and from the citadel should be via air locks and cleansing stations to decontaminate personnel entering the citadel.

4.11.8 A means of monitoring the level of overpressure within a citadel should be provided.

4.11.9 Doors, hatches and other closures that are part of the citadel boundary should be clearly marked as such.

4.11.10 All openings into the citadel should be capable of being closed to form a gastight seal. In the case of fluid systems with overboard discharges that are required to be open for operational reasons, these should be fitted with water seals to prevent the ingress of external air. Arrangements should be made to re-circulate air for ventilation/air conditioning purposes, such as galley air, and where necessary, provide bleed valves such that air may be purged via the air locks/cleansing stations without allowing external air to re-enter the citadel. The arrangements for re-circulation and fresh air intakes should take into account the maximum permitted levels of CO_2 and any other gases/ odours that may prejudice the safety of crew and embarked personnel.

4.11.11 In the case of machinery spaces that are to be kept 'clean' during NBC states by closures, combustion air should be trunked directly to the prime movers and adequate cooling is to be provided within these spaces to maintain safe equipment operation. Arrangements should be provided to permit engines to breath as required for full power operational requirements. *See* 5.11 for requirements for machinery enclosures.

4.11.12 A means of preventing adherence of contamination and for decontamination of the outside of the ship should be provided by pre-wetting/wetting systems. Adequate means of drainage should be provided for pre-wetting/wetting water. The siting of nozzles and drainage arrangements should be arranged to avoid build-up of water and potential ingress of water into air intakes for ventilation and machinery air intakes.

4.11.13 A means of monitoring, indicating and warning of NBC contamination should be provided.

4.11.14 Nuclear shelter positions for ship's crew and embarked personnel should be identified. These positions should be provided with adequate means of ventilation capable of maintaining the atmosphere with a maximum CO_2 level of 1,5 per cent for a defined period of time.

4.12 Electromagnetic compatibility (EMC)

4.12.1 Propulsion, steering, navigation and other essential systems, including weapons systems are to be designed and installed such that their performance does not degrade from the manufacturer's specifications as a result of susceptibility to electromagnetic interference generated during both normal operation and during military activities.

4.12.2 An EMC test plan is to be established, an EMC analysis carried out and a test report produced in accordance with the requirements and guidelines of IEC 60533 *Electrical Installations in Ships, Electromagnetic Compatibility* or equivalent requirements of the Naval Authority as defined in an appropriate naval standard. Regard is to be given to the fact that EMC requirements for systems installed on board naval ships may be more onerous due to the high concentration of electronic equipment, transmitters and receivers located in close proximity. Details are to be submitted for appraisal.

4.12.3 Systems are to comply with the emission limits and minimum immunity requirements of the Naval Authority as defined in an appropriate naval standard. This may require systems complying with emissions and immunity requirements of IEC 60533 *Electrical Installations in Ships, Electromagnetic Compatibility* to be subjected to additional testing in order to demonstrate the requirements of the Naval Authority are satisfied unless the EMC analysis clearly identifies such testing to be unnecessary. Details are to be submitted for appraisal.

4.13 Machinery interlocks

4.13.1 Interlocks are to be provided to prevent starting of engines under conditions that could hazard the machinery. These are to include 'turning gear engaged', 'low lubricating oil pressure where oil pressure is essential for the prevention of damage during start-up', 'shaft brake engaged' and where machinery is not available due to maintenance or repairs. The interlock system is to be arranged to 'fail safe'.

4.14 Stopping of machinery

4.14.1 Diesel engines, gas and steam turbines, and other prime movers are to be provided with a means of emergency stop, capable of being activated at a position outside the compartment in which the machinery is located. The arrangements are to be fully independent of control and alarm systems, and are to ensure a safe and controlled shutdown of machinery. Where such arrangements depend upon programmable electronic equipment, they are to comply with the relevant requirements in Pt 9, Ch 1,2.11.

4.14.2 Emergency stops are to be designed to minimize the risk of accidental or unauthorized operation.

4.15 Failure of control operating medium

4.15.1 Diesel engines and gas turbines are to be capable of operation at the maximum continuous power after loss or reduction of the normal control system operating medium, e.g. hydraulic, pneumatic or electrical, in accordance with the requirements in 4.15.2 to 4.15.4.

4.15.2 All electrical controls and alarms, necessary for operation of diesel engines and gas turbines, are to remain operational using an emergency backup supply system (that may be battery powered) for a period of at least one hour after total failure of the main electrical supply. Diesel engines and gas turbines are to be capable of being started and operated throughout the range of ambient conditions in Pt 1, Ch 2,4.4 without the use of power from the ship's electrical supply system.

4.15.3 Any hydraulic, pneumatic or electrical control and alarm systems are to be arranged so that any diesel engine or gas turbine operating at the time of failure will continue to operate safely for a period of at least one hour under the control mode selected at the time of failure, i.e. successful control system changeover is not to be a precondition for continued safe operation. Engine monitoring and alarm systems required by the Rules are to be available at all times.

4.15.4 Emergency hand control is to be provided where necessary to enable the requirements for safe operation called for by 4.15.2 to be assured following auto and/or remote control system failure.

4.16 Control of rotating systems

4.16.1 An effective means of setting and adjusting the rotation speed of each complete rotating system (e.g. prime mover, gearing, shafting, alternator and propeller) to defined operating performance requirements is to be provided. The means and arrangements for adjusting the speed of rotation are to recognize any requirements for the avoidance of running in barred speed range(s).

4.16.2 All prime movers are to be provided with an efficient governor arrangement that is capable of controlling the prime mover's set speed within defined limits when subject to load changes. The performance of governors is to recognize the rotating system's specification of capability during normal, emergency and reversionary modes of operation. For power train systems, the inertia of components and associated requirements for speed control of the prime mover are to be addressed. *See* Part 2, Chapters 1, 2 and 3 for the respective performance requirements of governors fitted to diesel engines, gas turbines and steam turbines.

4.16.3 The arrangements for control of rotating systems are to comply with Pt 9, Ch 1 as applicable and are to be such that failure in any item of equipment in the control system does not cause a hazard to the operation of the prime mover. The arrangements are to comply with the requirements of 4.15 as applicable.

4.17 Survey and refit

4.17.1 Arrangements are to be provided for the discharge of fuels and lubricating oils from the ship to a safe off ship facility where operational requirements necessitate system cleaning and refit.

4.18 Electromagnetic hazards

4.18.1 All equipment, operating and observation positions are, as far as is practicable, to be sited clear of sources of electromagnetic energy such as radars, communication transmitters or lightning conductors.

4.18.2 Where sources of electromagnetic energy or the swept beam of radar aerials are in close proximity to equipment operating and observation positions, suitable warning notices and markings are to be provided to draw attention to the potential hazards.

4.19 Flexible hose and bellows expansion piece registers

4.19.1 Flexible hoses and bellows expansion piece units are life limited and a Register of such units is to be established and maintained for all units installed on board where failure may result in any of the following:
(a) Fire spread.
(b) Flooding that could lead to the loss of any compartment.
(c) Loss of availability of a mobility or ship type system.
(d) Danger to personnel from release of stored energy.

4.19.2 The following information is to be included in the Register:
(a) Equipment designation and location on ship.
(b) Purpose.
(c) Hose specification including end fittings.
(d) Date of manufacture and cure date in the case of rubber units.
(e) Date of installation.
(f) Date of pressure/installation testing.
(g) Routine inspection interval.
(h) Pressure testing
(j) Due for renewal.
A typical Flexible Hose Register format is shown in Table 2.4.3.

Table 2.4.3 Typical Flexible Hose Register

<table>
<tr><td colspan="5">Flexible Hose Register</td></tr>
<tr><td colspan="3">System</td><td colspan="2">Length</td></tr>
<tr><td colspan="3">Equipment</td><td colspan="2">Nominal bore</td></tr>
<tr><td colspan="3">Position</td><td colspan="2">Offset angle between elbow and fittings</td></tr>
<tr><td colspan="3">End fitting 1</td><td colspan="2">End fitting 2</td></tr>
<tr><td colspan="3">Purpose</td><td colspan="2">Max working pressure</td></tr>
<tr><td colspan="3">Specification</td><td colspan="2">Hose test pressure</td></tr>
<tr><td>Manufacturer's part No.</td><td>Cure date</td><td>Date fitted</td><td>Date for renewal</td><td>Inspection,test,change date and remarks</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

4.19.3 Flexible hoses and bellows expansion pieces are to comply with the requirements of Pt 7, Ch 1,13 and 14 as applicable and should be labelled in order to provide a clear trace between the Register and equipment.

4.19.4 A Naval Authority may require the scope of a flexible hose or expansion bellows piece Register for purposes other than those detailed in 4.19.1.

■ *Section 5* Machinery space arrangements

5.1 Machinery spaces

5.1.1 Machinery spaces of category A are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or

(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power of not less than 375 kW; or

(c) any oil-fired boiler or oil fuel unit.

5.1.2 Machinery spaces are all machinery spaces of Category A and all other spaces containing propulsion machinery, boilers, oil fuel units (defined in 5.1.3), steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilizing, ventilation and air-conditioning machinery, and similar spaces and trunks to such spaces.

5.1.3 An oil fuel unit is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 N/mm^2.

5.1.4 Aluminium is not to be used for the crowns or casings of Category A machinery spaces. Where the hull is constructed of aluminium or composite material, consideration will be given to the use of aluminium for the crown or casings for such spaces where the fire safety issues relating to the use of aluminium have been addressed to the satisfaction of LR.

5.1.5 Windows are not to be fitted in machinery space boundaries. However this does not preclude the use of glass in control rooms within the machinery space.

5.1.6 Machinery space skylights, where fitted, are not to contain glass.

5.2 Accessibility

5.2.1 Accessibility, for attendance and maintenance purposes, is to be provided in all spaces for machinery and engineering systems and equipment.

5.2.2 Removal routes for items of machinery and equipment are to be established where routine removal of major items of equipment is envisaged.

5.3 Machinery fastenings

5.3.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the ship's structure to the satisfaction of the Surveyor.

5.3.2 Machinery may be installed on rafts of rigid construction and these are to be of robust construction to ensure that alignment is maintained under all conditions of ship motion. The rafts are to be securely fixed to the ship's structure.

5.4 Resilient mountings

5.4.1 The dynamic angles of inclination in Table 2.4.1 may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

5.4.2 Limit stops are to be fitted as necessary to ensure that manufacturers’ limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

5.4.3 Mounts are to be shielded from the possible detrimental effects of oil and where appropriate, paint and other contaminants.

5.5 Resin chocks

5.5.1 Synthetic resin compounds as materials for chocks under machinery where alignment is important are to be of a type accepted by LR.

5.5.2 The use of resin for chocking gas turbine casings or similar high temperature applications is not acceptable.

5.5.3 Where the Naval Authority has defined military requirements that include design and installation of machinery to withstand shock, the resin is to be approved for this application.

5.6 Ventilation

5.6.1 All spaces including engine and pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions.

5.6.2 Machinery spaces are to be sufficiently ventilated so as to ensure that when machinery or boilers therein is operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for operation of machinery.

5.6.3 The selection and arrangements of machinery and associated equipment are to minimize the emission of noxious substances into machinery spaces.

5.7 Fire protection

5.7.1 All surfaces of machinery where the surface temperature may exceed 220ºC and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil the insulation is to be encased in steel or equivalent.

5.8 Means of escape

5.8.1 Except as permitted in 5.8.2, two means of escape are to be provided from each machinery space of Category A. In particular, one of the following provisions are to be complied with:

(a) Two sets of steel ladders as widely separated as possible leading to doors in the upper part of the space similarly separated and from which access is provided to the open deck. In general, one of these ladders shall provide continuous fire shelter from the lower part of the space to a safe position outside the space. The shelter is to be of steel, insulated, where necessary and provided with a self-closing steel door. The shelter will not be required if, due to the special arrangement or dimensions of the machinery space, a safe escape route from the lower part of the space is provided.

(b) One steel ladder leading to a door in the upper part of the space from which access is provided to the open deck and additionally, to the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

Alternative arrangements is accordance with the requirements of the Naval Authority may also be acceptable

5.8.2 Where agreed by the Naval Authority, in a NS3 category ship, one of the means of escape required in 5.8.1 may not be required with due regard being paid to the dimension and disposition of the upper part of the space.

5.8.3 When access to any machinery space of Category A is provided at a low level from an adjacent shaft tunnel, there is to be provided in the shaft tunnel, near the watertight door, a light steel fire-screen operable from each side.

5.8.4 From machinery spaces other than those of Category A, escape routes are to be provided having regard to the nature and location of the space and whether persons are normally employed in the space.

5.8.5 Lifts are not to be considered as forming one of the required means of escape.

5.9 Communications

5.9.1 At lease two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled.

5.9.2 One of the two means required by 5.9.1 shall visually indicate the order and response, both at the engine room control station and on the bridge.

5.9.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

5.10 Personnel safety

5.10.1 All moving parts of machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

5.10.2 Protection is to be provided to prevent injury from hot surfaces, i.e. by suitable lagging or guards.

5.10.3 Assemblies incorporating pre-loaded springs are to be engineered such that spring forces can be released in a controlled and safe manner during the removal and/or disassembly process.

5.10.4 Open ends from relief valve pressure release pipes are to be arranged so that any discharge is directed away from positions where personnel might reasonably be expected to be. If relief pipes cross citadel boundaries, the relief valves are to relieve through sealed tundishes able to withstand the citadel overpressure.

5.10.5 Sufficient deck plates, platforms and handholds are to be fitted to provide safe access to all parts of the machinery and ensure safe passageway between machinery and adjacent equipment.

5.10.6 Materials used in the construction of machinery and installation of engineering systems are not to be a recognized hazard to personnel. This includes the prohibition of asbestos except in the following applications where agreed by LR and the Naval Authority:

(a) Vanes used in rotary vane compressors and rotary vane pumps;

(b) Watertight joints and linings used for the circulation of fluids when at high temperature (in excess of 350ºC) or pressure (in excess of 7 x 10^6 Pa) there is a risk of fire, corrosion or toxicity;

(c) Supple and flexible thermal insulation assemblies used for temperatures above 1000ºC.

5.10.7 Means are to be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access, *see also* Pt 10, Ch 1,16.8.1.

5.11 Machinery enclosures

5.11.1 Where machinery is installed within enclosures, the requirements of 5.11.2 to 5.11.11 are to be complied with.

5.11.2 Enclosures are to be treated as unattended machinery spaces and comply with the relevant Rules for such spaces and installed equipment.

5.11.3 Enclosures are, as far as reasonably practicable, to be gas tight with flexible sealing arrangements between air induction, exhaust and ventilation systems.

5.11.4 The arrangements are to prevent contamination of the machinery space in an NBCD environment.

5.11.5 Enclosures are to be constructed to form a suitable fire boundary.

5.11.6 An access door, adequate internal lighting and observation windows, with suitable fire rating, are to be located to afford a clear view of both sides of the equipment within the enclosure.

5.11.7 Suitable means of drainage of any liquids which may accumulate are to be provided without compromising the citadel.

5.11.8 Enclosures are to be suitably ventilated and designed to maintain all components within their safe working temperature under all operating conditions. The ventilation system is to be independent from the machinery space ventilation arrangements and provided with suitable closing devices for fire control purposes.

5.11.9 Enclosures are to be provided with a means to enable gas purging with a portable fan in addition to the fixed ventilation system.

5.11.10 Means are to be provided to monitor the enclosure air temperature and differential pressure.

5.11.11 Machinery spaces and enclosures are to be provided with fire detection, alarm and extinction systems in accordance with the fire safety arrangements required by the Regulations in Vol 1, Pt 1, Ch 2,1.1.9. For unattended machinery spaces a fire detection system in accordance with Pt 9, Ch 1,3.5 is to be fitted.

■ *Section 6* Diesel engines

6.1 Design

6.1.1 For details of design requirements, *see* Pt 2, Ch 1.

6.2 Construction and welding

6.2.1 Where engine structures are fabricated, assembly is to be carried out to an approved welding and stress relief heat treatment procedure.

6.2.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

6.2.3 Forgings and castings are to be examined at the manufacturer's works.

6.3 Hydraulic testing

6.3.1 Items are to be tested by hydraulic pressure as indicated in Table 2.6.1.

6.3.2 Where a manufacturer has demonstrated to LR that they have an acceptable quality management system, a manufacturer's hydraulic test certificate may be accepted for engine driven pumps as detailed in Table 2.6.1. Recognition and acceptance of the works quality control processes can be by one of the following routes:

(a) Approval under the LR Quality Scheme for Machinery.
(b) Approval of an alternative quality scheme recognized by LR.
(c) Approval by LR through auditing of the manufacturer's quality system.

6.4 Non-destructive testing

6.4.1 Non-destructive tests of components are to be carried out to an approved procedure. *See also* Vol 1, Pt 2, Ch 1,12.

6.5 Engine type testing

6.5.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

6.5.2 Guidelines for type testing of engines will be supplied on application.

6.5.3 An engine type is defined in terms of:

- basic engine data: e.g. bore, stroke;
- working cycle: 2 stroke, 4 stroke;
- cylinder arrangement: in-line, vee;
- cylinder rating;
- fuel supply: e.g. direct, or indirect injection;
- gas exchange: natural aspiration, pressure charging arrangement.

Table 2.6.1 Test pressures

Item	Test pressure
Fuel injection equipment including: Pump body, pressure side Valve Pipe	The lesser of 1,5*p* or *p* + 295 bar
Cylinder cover cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5*p*
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5*p* Water side: the greater of 4,0 bar or 1,5*p*
Scavenge pump cylinder	4,0 bar

NOTES
1. *p* is the maximum working pressure, in bar, in the item concerned.
2. Pumps used in jerk or timed pump systems need only have the assembled high pressure containing components hydraulically tested.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

6.5.4 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

6.5.5 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 7* Turbo-chargers

7.1 Design

7.1.1 For details of design requirements, *see* Pt 2, Ch 1.

7.2 Type testing

7.2.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger it is to be completely dismantled for examination of all parts.

7.2.2 Alternative arrangements will be considered.

7.3 Dynamic balancing

7.3.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

7.4 Overspeed tests

7.4.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

7.5 Mechanical running tests

7.5.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

7.5.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test to a representative sample of turbo-chargers.

■ *Section 8* Gas turbines

8.1 Design

8.1.1 For details of design requirements, *see* Pt 2, Ch 2.

8.2 Construction under survey

8.2.1 All gas turbine units intended for installation in a ship classed or intended to be classed with LR are to to be constructed in accordance with LR's Quality Assurance Scheme for Machinery, *see* Pt 1, Ch 1,8.

8.3 Dynamic balancing

8.3.1 All compressor and turbine rotors as finished-bladed and complete with all relevant parts such as half-couplings, are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

8.4 Hydraulic testing

8.4.1 Where design permits, casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure. Where the operating temperature exceeds 300°C the test pressure is to be suitably corrected.

8.4.2 Where hydraulic testing is impracticable, non-destructive tests by ultrasonic or radiographic methods are to be carried out on the entire circumference of all casing parts with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide documentary evidence that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the operational performance of the gas turbine.

8.4.3 The shell and tube arrangement of intercoolers and heat exchangers are to be tested to 1,5 times their maximum working pressure.

8.5 Overspeed tests

8.5.1 Before installation, it is to be satisfactorily demonstrated that the gas turbine is capable of safe operation for five minutes at 5 per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

8.5.2 Where it is impracticable to overspeed the complete installation, each compressor and turbine rotor completely bladed and with all relevant parts such as half-couplings, are to be overspeed-tested individually at the appropriate speed.

■ *Section 9* Steam turbines

9.1 Design

9.1.1 For details of design requirements, *see* Pt 2, Ch 3.

9.2 Stability testing of turbine rotors

9.2.1 All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400ºC are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors constructed from two or more forged components joined by welding. The test may be carried out at the forge or turbine builders' works:

(a) after heat treatment and rough machining of the forging; or

(b) after final machining; or

(c) after final machining and blading of the rotor.

The stabilizing test temperature is to be not less than 28ºC above the maximum steam temperature to which the rotor will be exposed, and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, *see* Vol 1, Part 2. Other test procedures may be adopted if approved.

9.2.2 Where main turbine rotors are subjected to thermal stability tests at both forge and turbine builders' works the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but if such tests are carried out, the requirement for main turbine rotors will be generally applicable.

9.3 Balancing

9.3.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced to the Surveyor's satisfaction, in a machine of sensitivity appropriate to the size of rotor.

9.4 Hydraulic tests

9.4.1 Manoeuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

9.4.2 The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing, or to 2,0 bar, whichever is the greater.

9.4.3 For test purposes, the cylinders may be sub-divided with temporary diaphragms for distribution of test pressures.

9.4.4 Condensers are to be tested in the steam space to 1,0 bar. The water space is to be tested to the maximum pressure which the pump can develop at ship's full draught with the discharge valve closed plus 0,7 bar, with a minimum test pressure of 2,0 bar. Where the operating conditions are not known, the test pressure is to be not less than 3,4 bar. *See* Pt 7, Ch 1.

9.5 Indicators for movement

9.5.1 Indicators for determining the axial position of rotors relative to their casings, and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

9.6 Weardown gauges

9.6.1 Main and auxiliary turbines are to be provided with bridge weardown gauges for testing the alignment of the rotors.

■ *Section 10* Gearing

10.1 Design

10.1.1 For details of design requirements, *see* Pt 3, Ch 1.

10.2 Construction and welding

10.2.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

10.2.2 Where welding is employed in the construction of wheels and gearcases, the welding procedure is to be approved before work is commenced. For this purpose, welding procedure approval tests are to be carried out with satisfactory results. Such tests are to be representative of the joint configuration and materials. All welds are to have a satisfactory surface finish and contour. Magnetic particle or liquid penetrant examination of all important welded joints is to be carried out.

10.2.3 Welded constructions are to be stress relief heat treated on completion of welding.

10.2.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

10.3 Accuracy of gear cutting

10.3.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

10.4 Non-destructive testing

10.4.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

10.4.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

10.4.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

10.5 Dynamic balancing

10.5.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

10.5.2 The permissible residual unbalance, *U*, is defined as follows:

$$U = \frac{60\ m}{R} \times 10^3 \text{ g mm for } R < 3000$$

$$U = \frac{24\ m}{R} \times 10^3 \text{ g mm for } R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element.

10.5.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

10.6 Meshing tests

10.6.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

10.6.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

10.6.3 For gears without crowning or helix correction the marking is to be not less than shown in Table 2.10.1.

Table 2.10.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5 Q ≥ 6	50% b x 40% h_w + 40% b x 20% h_w 35% b x 40% h_w + 35% b x 20% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears the values of h_w should be increased by a further 10%.	

10.6.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

10.6.5 For gears with crowning, or helix correction the marking is to correspond to the designed no load contact pattern.

10.6.6 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board the craft.

10.6.7 The full load tooth contact marking is to be not less than shown in Table 2.10.2.

Table 2.10.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5 Q ≥ 6	60% b x 70% h_w + 30% b x 50% h_w 45% b x 60% h_w + 35% b x 40% h_w
NOTES 1. Where b is the face width and h_w is the working tooth depth. 2. For spur gears the values of h_w should be increased by a further 10%.	

10.6.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

10.6.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a.\alpha_n}{9000} + 0,1 \text{ mm}$$

where

α_n = normal pressure angle, in degrees
a = centre distance, in mm.

■ *Section 11* Shafting systems

11.1 Design

11.1.1 For details of design requirements, *see* Pt 3, Ch 2.

11.2 Construction

11.2.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

11.2.2 Before boring the sternframe, the ships structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

11.3 Shaft bearing clearances

11.3.1 After installation of the screwshaft and any shafting installed in bearings fitted in stern bushes or shaft bearings in ‘A’ and ‘P’ brackets, the bearing clearances are to be measured and recorded. The records are to be placed on board.

■ *Section 12* Propellers

12.1 Design

12.1.1 For details of design requirements, *see* Pt 4, Ch 1.

12.2 Construction and welding

12.2.1 Castings are to be examined at the manufacturer's works.

12.2.2 All finished propellers are to be examined for material defects, and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of Vol 1, Pt 2, Ch 9,1.

12.3 Shop tests of keyless propellers

12.3.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalize before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

12.3.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

12.4 Shop tests of controllable pitch propellers

12.4.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

12.4.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

12.5 Final fitting of keyless propellers

12.5.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

12.5.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimize stress raising effects.

12.5.3 The outside of the propeller boss is to be hard stamped with the following details:

For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0ºC and 35ºC, in mm.
For the dry fitting method, the push-up load at 0ºC and 35ºC, in Newtons.

12.5.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

12.6 Final fitting of keyed propellers

12.6.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

■ *Section 13* Water jet units

13.1 Design

13.1.1 For details of design requirements, *see* Pt 4, Ch 3.

13.2 Construction and welding

13.2.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

13.2.2 Welded components are to comply with the requirements of Vol 1, Pt 3, Ch 3, and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

13.3 Testing

13.3.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

13.3.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent standard.

■ *Section 14* Thrusters

14.1 Design and construction

14.1.1 For details of design and construction requirements, *see* Pt 4, Ch 2.

14.2 Azimuth thrusters

14.2.1 The performance specified for the craft is to be demonstrated.

14.2.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

14.3 Tunnel thrusters

14.3.1 It is to be demonstrated that the thruster unit meets the specified performance.

Section 15
Steering systems

15.1 Design

15.1.1 For details of design requirements, *see* Pt 6, Ch 1.

15.2 Construction

15.2.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

15.3 Type testing

15.3.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

15.4 Testing

15.4.1 After installation on board the steering unit is to be subjected to the applicable hydrostatic and running tests.

15.4.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.

(b) The steering power units, including transfer between steering power units.

(c) The isolation of one power actuating system, checking the time for regaining steering capability.

(d) The hydraulic fluid recharging system; (may be effected at the dockside).

(e) The alternative power supply and emergency hand pump operation.

(f) The steering controls, including transfer of control and local control.

(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable; (may be effected at the dockside).

(h) The alarms and indicators; (may be effected at the dockside).

(j) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated; (may be effected at the dockside).

Section 16
Sea trials

16.1 Sea trials requirements

16.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

16.2 Programme

16.2.1 Sea trials are to include the demonstration of:

(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.

(b) The effectiveness of the steering gear control systems (*See* 15.4.2).

(c) Manoeuvring, to include:
- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices, and associated indicators; and
- alarms.

(d) The redundancy arrangements.

(e) Tooth contact markings in geared installations using a recognized technique. The marking is to be as detailed in 10.6.

(f) For controllable pitch propellers, the pitch setting under failure conditions.

(g) Operation of sliding watertight doors under working conditions.

(h) Anchoring test to demonstrate that the windlass with brakes, etc., functions satisfactorily, and that the power to raise the anchor can be developed and satisfies the Rule requirements. *See* Vol 1, Pt 3, Ch 5,8.

(j) Operation of bilge and dewatering systems to dry compartments.

16.3 Performance testing

16.3.1 The performance of main propulsion machinery is to be demonstrated at full power in accordance with an agreed trials schedule. Engine changeover arrangements are to be demonstrated where applicable.

16.3.2 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

16.3.3 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

16.3.4 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

16.3.5 Overloading of machinery is not to occur under continuous astern power.

■ *Section 17* Failure Mode and Effects Analysis (FMEA)

17.1 General

17.1.1 A FMEA is to be carried out in accordance with 17.1.2 to 17.1.6 for systems (a), (b) and (c) as specified in 3.3.8. The analysis is to demonstrate that suitable risk mitigation has been achieved so that the system will tolerate a single failure with regard to the criteria specified in Pt 1, Ch 1,4.2.9 and 4.2.10. The scope of analysis required for each system is defined in the respective parts of the Rules.

17.1.2 The FMEA is to be carried out using the format presented in Table 2.17.1 or an equivalent format that addresses the same safety issues. Analysis in accordance with IEC 812, *Analysis for System Reliability – Procedures for Failure Mode and Effects Analysis*, or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

17.1.3 The FMEA is to be organized in terms of items of equipment and function. The effects of item failures at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

17.1.4 The FMEA is to:

(a) Identify the equipment or sub-system, mode of operation and the equipment.
(b) Identify potential failure modes and their causes.
(c) Evaluate the effects on the system of each failure mode.
(d) Identify measures for reducing the risks associated with each failure mode.
(e) Identify trials and testing necessary to prove conclusions.

17.1.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

17.1.6 Where FMEA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than a specific analysis of the software code.

■ *Section 18* Fin stabilisers

18.1 Design and construction

18.1.1 For requirements relating to fin stabiliser scantlings, arrangements, foundations, supporting structure and watertight integrity, *see* Vol 1, Pt 3, Ch 3,1.

18.1.2 Fin stabiliser actuating systems are to be consistent with the requirements of Vol 2, Pt 6, Ch 1,5 as applicable.

18.1.3 Materials for components of fin stabilisers are to be consistent with the requirements of Vol 2, Pt 6, Ch 1,3 as applicable.

18.1.4 Control and electrical engineering systems are to comply with the requirements of Vol 2, Pt 9 and Pt 10 respectively as applicable.

18.1.5 Attention is to be given to any relevant requirements of the Naval Authority.

Table 2.17.1 Failure mode and effects analysis

System				Element							
Item No.	Component description	Function	Mode of operation	Failure mode	Failure cause	Failure detection	Effect of failure		Severity	Corrective action	Remarks
							On item	On system			

NOTE
The severity category is to be in accordance with the following:
(a) Catastrophic; (b) Hazardous; (c) Major or (d) Minor.

18.2 Performance and control

18.2.1 Fin stabilisers are to be capable of satisfying the specified functional performance requirements as detailed in the design statement, *see* 3.3.14(a).

18.2.2 For retractable type fin stabilisers, the servo system arrangements are to be capable of extending the fins fully at the ship's maximum service speed and in the most onerous environmental conditions, for which the ship is designed, *see* Vol 1, Pt 5, Ch 2,2.3.

18.2.3 After setting to work, the fin stabiliser system is to be entirely automatic irrespective of ship speed or sea state.

18.2.4 Failure of any part of the fin stabiliser unit or its control system is not to result in an unsafe condition which will have detrimental affect on the ship's operating or sea-keeping capability.

18.2.5 In the event of failure of the fin actuating system, a hand pump is to be provided, mounted in a readily accessible position, which is capable of centralising the fin in the absence of electrical power, and being operated by no more than two men when the ship is stopped.

18.3 Control, monitoring and alarms

18.3.1 Fin stabiliser actuating control arrangements are to be located in readily accessible positions that have means of communication provided to machinery control station and the navigating bridge.

18.3.2 Fin stabiliser function indicators are to be provided on the navigating bridge and at the main machinery control station.

18.3.3 The fin position feedback signals are to be independent of the actuating systems.

18.3.4 Alarms and monitoring requirements are indicated in Table 2.18.1.

18.3.5 All alarms associated with fin stabiliser faults are to be indicated on the navigating bridge and in accordance with the requirements of Pt 9, Ch 1.

18.4 Trials and testing

18.4.1 After installation on board the fin stabiliser unit is to be subject to hydrostatic and running tests.

18.4.2 Testing and trials are to be carried out in accordance with a procedures that have been agreed between the Shipyard, Owner/Operator and LR. The testing is to demonstrate:

(a) The stabiliser system including the functional performances specified in the design statement required by 3.3.14(a).
(b) Extending and retracting the fins.
(c) Alternative electrical power supply arrangements where provided and functional capability of the emergency hand pump arrangements.
(d) Stabiliser controls.
(e) The alarms and indicators.
(f) Where the stabiliser system is designed to avoid hydraulic locking, this feature is to be demonstrated.

Table 2.18.1 Alarms and monitoring

Item	Alarm	Note
Stabiliser system active	-	Indication, *see* 18.3
Deviation of actual fin angle position from that demanded	Fault	*See* 18.3.3
Fin angle limit exceeded	Fault	
Roll angle	High	
Position indicator of fin	—	Indication, *see* Vol 1, Pt 3, Ch 3,3.1.16
Fin stabiliser power units, power	Failure	—
Control system power	Failure	—
Fin stabiliser hydraulic oil tank level	Low	Each tank to be monitored
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored (*see* Note)
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and to be activated when (for example):
Position of the variable displacement pump control system does not correspond with given order; or incorrect position of 3-way full flow valve or similar in constant delivery pump system in detected.

■ *Section 19*
Fired galley arrangements

19.1 Oil and liquefied petroleum gas fired galleys

19.1.1 The use of oil or liquefied petroleum gas fired galleys is acceptable provided arrangements are also acceptable to the Naval Authority and the requirements of 19.1.2 to 19.1.6 are complied with.

19.1.2 The oil fuel tank is to be located outside the galley and is to be fitted with approved means of filling and venting.

19.1.3 The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley.

19.1.4 The galley is to be well ventilated.

19.1.5 When liquefied petroleum gas is used, bottles are to be stored on the open deck or in a well ventilated space which only opens to the open deck. Protection against military action is to be to the satisfaction of the Naval Authority and the arrangements are to be acceptable to LR.

19.1.6 The piping design is to be in accordance with the requirements of Pt 7, Ch 1 as applicable.

Section

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and process equipment, heating and steam raising boilers and pressure pipes. The allocation of Class is determined from the design criteria referenced in Pt 7, Ch 1 and Part 8.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships*, Book A Procedure MQPS 0-4.

1.1.3 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes, *see* Section 6 for oxy-acetylene welding of pipes.

1.1.4 For pressure vessels which only have circumferential seams, *see* Pt 8, Ch 1,1.5.4 and Pt 8, Ch 2,1.5.5.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures.

1.2.2 The procedures are to include the regular systematic supervision of all welding, and the welders are to be subjected by the work's supervisors to periodic tests for quality of workmanship. Records of these tests are to be kept and are to be available for inspection by the Surveyors.

1.2.3 All welding is to be to the satisfaction of the Surveyors.

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved where required by Pt 8, Ch 1,1.6 and Pt 8, Ch 2,1.6.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved in accordance with MQPS 0-4.

2.2 Materials of construction

2.2.1 Materials used in welded construction are to be readily weldable and shall have proven weldability.

2.2.2 Materials are to be supplied by firms that have been approved in accordance with Vol 1, Part 2.

2.2.3 Where the construction details are such that materials are subject to through thickness strains, consideration should be given to using materials with specified through thickness properties as specified in Vol 1, Part 2.

2.2.4 Where the construction requires post weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.2.5 The identity of materials is to be established by way of markings, etc., so that traceability to the original manufacturer's certificate is maintained.

2.3 Cutting of materials

2.3.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

2.3.2 Cold shearing should not be used on materials in excess of 25 mm thick and, where used, the cut edges are to be cut back by machining or grinding for a minimum distance of 3 mm.

2.3.3 Material which has been thermally cut is to be machined or ground back to remove all oxides, scale and notches.

2.3.4 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure freedom from cracking. In these cases the cut edges are to be machined or ground back a distance of at least 2,0 mm, unless it has been demonstrated that the cutting process has not damaged the material.

2.3.5 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal; weld repair may only be performed with the agreement of the Surveyors.

2.3.6 All plate edges, after being cut. shall be examined for defects, including laminations, to ensure that these are free from cracks. Visual methods may be augmented by other techniques at the discretion of the Surveyors.

2.3.7 Edges that have been cut by machining or chipping, which will not be subsequently covered by weld metal, are to be ground smooth.

2.4 Forming shell sections and end plates

2.4.1 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

2.4.2 Plates may be formed to the required shape either hot or cold and by any process that does not impair the quality of the material. Tests to demonstrate the suitability of the forming process may be requested at the discretion of the Surveyors.

2.4.3 Wherever possible, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition should not be employed.

2.4.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the mechanical properties of the welds are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

2.4.5 Vessels manufactured from carbon or carbon manganese steel plates which have been hot formed or locally heated for forming are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition shall be heat treated in accordance with the material manufacturer's recommendations.

2.4.6 Where these steels are supplied in the as-rolled, normalized or normalized rolled condition, if hot forming is carried out entirely at a temperature within the normalizing range, subsequent heat treatment will not be required.

2.4.7 For alloy steel vessels, where hot forming is employed the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

2.4.8 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

2.4.9 In all cases where hot forming is employed, and for cold forming to an internal radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

2.5 Fitting of shell plates and attachments

2.5.1 Careful consideration is to be given to the assembly sequence to be employed, in order to minimize overall shrinkage and distortion and to reduce the build up of residual stresses.

2.5.2 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, the corrective measures adopted are to be to the satisfaction of the Surveyors.

2.5.3 Provision is to be made for retaining correct alignment during welding operations.

2.5.4 In all cases where tack welds are used to retain plates or parts in position prior to welding they are to be made using approved welding procedures.

2.5.5 Where temporary bridge pieces or strong-backs are used they are to be of similar materials to the base materials and are to be welded in accordance with approved welding procedures.

2.5.6 Where welding to clad materials, any fit-up aids and tack welds are to be attached to the base materials and not to the cladding.

2.5.7 The location of welded joints are to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

2.5.8 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the mis-alignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

2.5.9 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

2.5.10 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

2.5.11 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

2.6 Welding during construction

2.6.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking due cognisance of relevant safety precautions. Electrical meters are to be properly maintained and have current calibrations.

2.6.2 Welding consumables are to be suitable for the type of joint and grade of material to be welded and satisfactory storage and handling facilities are to be provided close to working areas.

2.6.3 Prior to use, welding consumables should be dried and/or baked in accordance with the consumable manufacturer's recommendations. The condition of welding consumables shall be subject to regular inspections.

2.6.4 All welders and welding operators are to be suitably skilled and qualified for the type of welding work to be undertaken.

2.6.5 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts.

2.6.6 Welding should be performed wherever possible in covered workshops. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

2.6.7 Surfaces of all parts to be welded are to be clean, dry and free from rust, scale and grease. Where prefabrication primers are applied over areas which will be subsequently welded, they are to be approved for that application.

2.6.8 Preheat shall be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level during welding and is to be to the satisfaction of the Surveyors.

2.6.9 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care should be taken to pre-warm and dry the weld joint.

2.6.10 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

2.6.11 Tack welds made in the root of the weld joint are to be removed in the process of welding the seam.

2.6.12 Where the welding process used is slag forming (e.g. manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

2.6.13 Wherever possible, full penetration welds are to be made from both sides of the joint. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

2.6.14 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

2.6.15 Where welding from one side only cannot be avoided, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

2.6.16 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

2.6.17 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

2.6.18 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, these shall be to the same standard as that required for the main vessel shell construction.

2.6.19 The attachment by welding of such fittings to the main pressure shell after post weld heat treatment is not permitted.

2.6.20 Completed welds shall be at least flush with the surface of the plates joined and have the shape and size specified in the approved drawings or specifications. Welds shall have an even contour and blend smoothly with the base materials.

2.6.21 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment. Tubes that have been expanded into headers or drums may be seal welded without further post weld heat treatment.

2.6.22 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

2.7 Tolerances for cylindrical shells

2.7.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.7.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in Table 3.2.1.

Table 3.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300 > 300 ≤ 460 > 460 ≤ 600 > 600 ≤ 900 > 900 ≤ 1200 > 1220 ≤ 1520 > 1520 ≤ 1900	1,0 per cent of internal diameter	1,2 mm 1,6 mm 2,4 mm 3,2 mm 4,0 mm 4,8 mm 5,6 mm
> 1900 ≤ 2300 > 2300 ≤ 2670 > 2670 ≤ 3950	19 mm	6,4 mm 7,2 mm 8,0 mm
> 3950 ≤ 4650 > 4650	19 mm 0,4 per cent of internal diameter	0,2 per cent of internal diameter

2.7.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one-quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in Table 3.2.1. This amount corresponds to x in Fig. 3.2.1.

2.7.4 Shell sections are to be measured for out-of-roundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.7.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of Table 3.2.1.

2.7.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in Table 3.2.2.

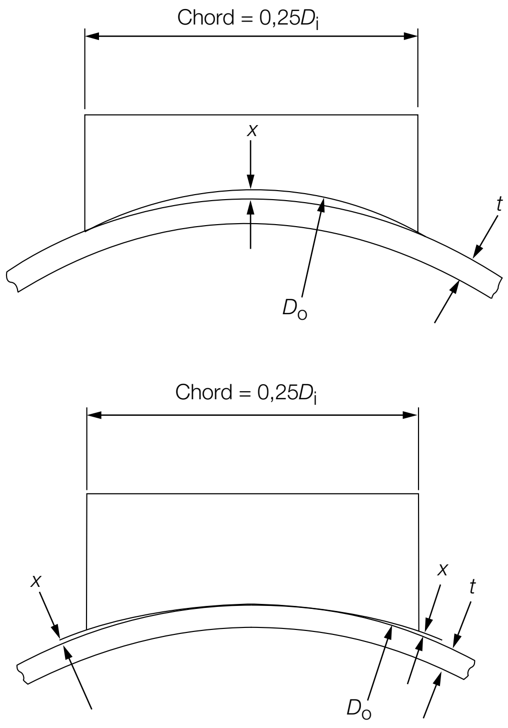


Fig. 3.2.1 Tolerances for cylindrical shells

Table 3.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thickness), in mm	Circumferential tolerance
300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

Section 3 Routine weld tests for pressure vessels

3.1 General requirements for routine weld tests

3.1.1 Routine or production weld tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

3.1.2 Routine test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

3.1.3 Routine weld tests are not required for Class 3 pressure vessels unless the minimum design temperature is below minus 10°C. However, occasional check tests may be requested at the discretion of the Surveyors.

3.1.4 Routine test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

3.1.5 In addition, routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

3.2 Test plate requirements

3.2.1 Two test plates, each of sufficient dimensions to provide one complete set of specimens, are to be prepared for each vessel and are to be welded as a continuation and simulation of the longitudinal weld joint.

3.2.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam with the agreement of the Surveyor. In these cases, the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

3.2.3 Where the vessel size or design results in a small number of longitudinal weld seams, with the agreement of the Surveyors, one test plate may be prepared for testing provided that the welding details are the same for each seam.

3.2.4 Test plate materials shall be of the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test plate shall be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimized.

3.2.5 Where there is a requirement for several routine tests to be welded, welding is to be performed by different welders, wherever possible.

3.2.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test weld prior to mechanical testing is not permitted.

3.2.7 Where the pressure vessel is required to be subjected to post weld heat treatment, the test weld shall be heat treated, after welding, in accordance with the same requirements. Subject to agreement with the Surveyor this may be performed separately from the vessel.

3.3 Inspection and testing

3.3.1 The test weld is to be subjected to the type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination shall be performed prior to removing specimens for mechanical testing, but after any post weld heat treatment.

3.3.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as follows.

3.4 Mechanical testing requirements

3.4.1 The test plates are to be machined to provide the following test specimens:

(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact, *see* Table 3.3.1.
(e) Macrograph and hardness survey of full weld section.
(f) Chemical analysis of deposited weld metal.

Table 3.3.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness *t* mm	Impact test temperature
Class 1	–10°C or above	All	5°C below the minimum design temperature or 20°C whichever is the lower
All Classes	Below –10°C	$t \leq 20$	5°C below the minimum design temperature
		$20 < t \leq 40$	10°C below the minimum design temperature
		Over 40	Subject to agreement

3.4.2 One set of specimens for mechanical testing is to be removed, as shown in Fig. 3.3.1 or Fig. 3.3.2 as appropriate for the Class of approval. Impact tests shall be removed and tested where required by Table 3.3.1.

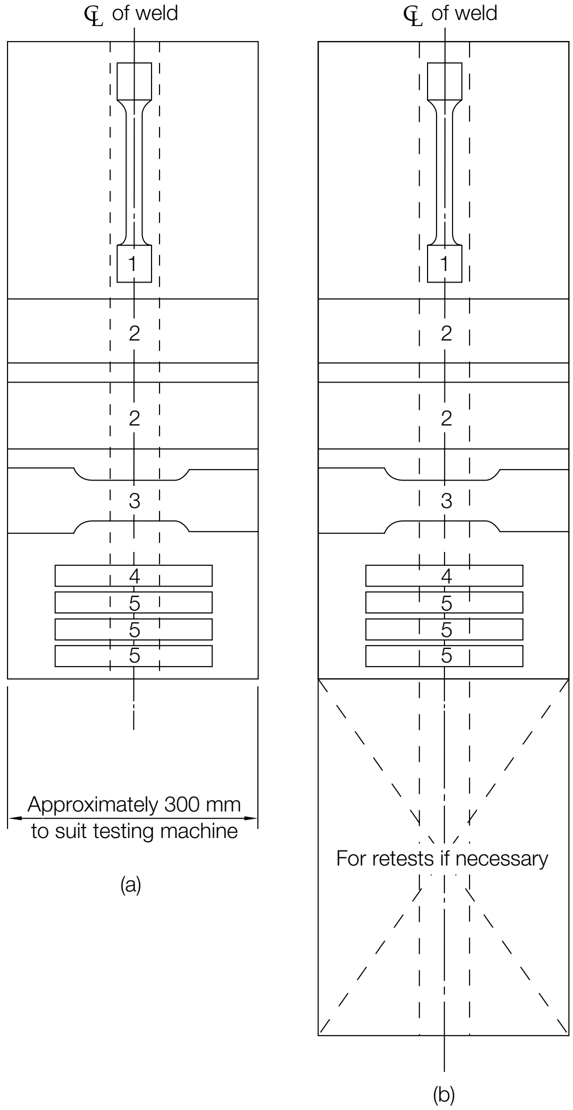


Fig. 3.3.1
Routine test plate – Test specimens for Class 1, 2/1 and 2/2

1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact test specimens.
   (For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

3.4.3 **Longitudinal tensile test for weld metal.** An all weld metal longitudinal tensile test is required and, for thicknesses in excess of 20 mm where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens shall be tested in accordance with the following requirements:

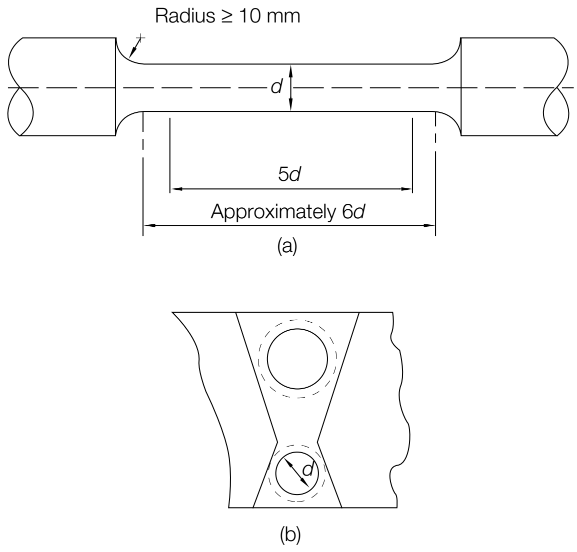


Fig. 3.3.2
Routine test plate – test specimens for Class 3

(a) The diameter and gauge length of the test specimen shall be in accordance with Fig. 11.2.1 in Chapter 11 of Vol 1, Part 2.

(b) For carbon steels, the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:

$$A = \frac{(980 - R)}{21,6}$$

where R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile test. In addition, this elongation is to be not less than 80 per cent of the minimum elongation specified for the plate.

(c) For other materials, the tensile strength and percentage elongation shall not be less than that specified for the base materials welded.

3.4.4 **Transverse tensile test for joint**. For the transverse tensile test, the weld reinforcement is to be removed, and shall meet the following requirements:

(a) Two reduced section tensile test specimens are to be cut transversely to the weld in accordance with the dimensions shown in Fig. 11.2.2 in Chapter 11 of Vol 1, Part 2.

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.

3.4.5 **Transverse bend test**. The bend test specimens shall meet the following:

(a) Four bend test specimens of rectangular section are to be cut from the test plate transversely to the weld, two bent with the outer surface of the weld in tension (face bend), and the other two with the inner surface in tension (root bend).

(b) The specimens are to be in accordance with Ch 11,2.1.3 of Vol 1, Part 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The plunger shall have the diameter shown in Table 3.3.2 based on the specimen thickness, *t*.

(d) After bending through an angle of at least 120°, there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen should not be cause for rejection, unless this is associated with a weld defect.

Table 3.3.2 Bend test requirements

Material grade	Former diameter
Up to Grade 460	3*t*
490 and 510	4*t*
13Cr Mo 45	5*t*
11Cr Mo 910	5*t*
Other materials	Subject to agreement

where t is the thickness of the bend test specimen.

3.4.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test plate near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.

(b) The specimen shall show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.

(c) Should there be any doubt as to the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.

(d) For carbon, carbon manganese and low alloy steels, a hardness survey is to be performed on the macro specimen using either a 5 kg or 10 kg load, testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed in the cap weld areas within 2 mm of the weld surface. The maximum recorded hardness shall not exceed 350 Hv10.

3.4.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared for testing when required by Table 3.3.1. Tests are to be performed and satisfy the following requirements:

(a) Each test is to consist of a set of three Charpy V-notch impact specimens and are to be removed with the vee notch perpendicular to the plate surface.

(b) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2 of Vol 1, Part 2.

(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations). Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.

(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.

(e) The average energy of a set of three specimens is not to be less than 27Joules or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,1.10.2 of Vol 1, Part 2.

3.4.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and shall be tested in accordance with and meet the following requirements:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.

(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces examined for defects. The weld shall be sound, with no evidence of cracking or lack of fusion or penetration and shall be substantially free from slag inclusions and porosity.

3.5 Failure to meet requirements

3.5.1 If any test specimen fails to meet the requirements, additional specimens may be removed and tested in accordance with Ch 1,1.11 of Vol 1, Part 2.

3.5.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established and the manufacturer is to take such steps as necessary to either:

(a) Remove the affected welds and have them re-welded to the Surveyor's satisfaction, or

(b) demonstrate that the affected production welds have acceptable properties.

■ *Section 4* Repairs to welds on fusion welded pressure vessels

4.1 General

4.1.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with the following:

(a) Major repairs shall not be carried out without the prior consent of the Surveyors.
(b) Where cracks have developed as a result of welding, these are to be reported to the Surveyors and the cause established prior to undertaking weld repair.
(c) Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove shall be subsequently ground to remove oxides and debris. In all cases, the groove shall have a profile suitable for welding.
(d) Prior to commencing repair welding, confirmation that the original defect has been removed is required by performing visual examination. This may be augmented by surface crack detection examination at the discretion of the Surveyors.
(e) Repair welding is to be performed using welding procedures agreed with the Surveyors.
(f) Where the pressure vessel requires post weld heat treatment in accordance with Section 5, this shall be performed after completion of the weld repairs.
(g) Weld repairs are to be shown by further non-destructive examinations to have removed the defect to the Surveyors satisfaction.

4.2 Re-repairs

4.2.1 In general, only two repair attempts are to be made of the same defect. Any subsequent repairs will be at the discretion of the Surveyors and may require the removal of the heat affected zone of the original repair.

■ *Section 5* Post weld heat treatment of pressure vessels

5.1 General

5.1.1 Fusion welded pressure vessels, where indicated in Table 3.5.1 are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

5.1.2 Tubes which have been expanded into headers or drums may be seal welded without further post weld heat treatment.

Table 3.5.1 Post weld heat treatment requirements

Type of steel	Plate thickness above which post weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr $^{1}/_{2}$Mo	All thicknesses	All thickness
2$^{1}/_{4}$Cr 1Mo	All thicknesses	All thicknesses
$^{1}/_{2}$Cr $^{1}/_{2}$Mo $^{1}/_{4}$V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration.	

5.1.3 Where the weld connects parts of different thicknesses, the thickness to be used when applying the requirements for post weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for connections to flanges, tubeplates and similar connections.

5.1.4 Parts are to be properly prepared for heat treatment, sufficient temporary supports are to be provided to prevent undue distortion or collapse of the structure and any machined faces are to be adequately protected against scaling.

5.1.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

5.2 Basic requirements for heat treatment of fusion welded pressure vessels

5.2.1 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained.

5.2.2 The heat treatment facilities shall be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the vessel temperature are to be provided. To this end, thermo-couples are to be attached such that they are in contact with the vessel.

5.2.3 Unless stated otherwise, post weld heat treatment is to be carried out by means of slow, even heating from 300°C to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually one hour per 25 mm of weld thickness), followed by slow even cooling to 300°C.

5.2.4 Recommended soaking temperatures and periods are given in Table 3.5.2 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

Table 3.5.2 Post weld soak temperatures and times

Material type	Soak temperature, °C (*see* Note)	Soak period
Carbon and carbon/manganese grades:	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr $^{1}/_{2}$Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2$^{1}/_{4}$Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
$^{1}/_{2}$Cr $^{1}/_{2}$Mo $^{1}/_{4}$V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post weld soak temperature shall be lower than the material tempering temperature.		

5.2.5 Where pressure vessels are of such dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

5.2.6 Where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases it may be necessary to carry out tests to show the effect of the proposed heat treatment.

■ *Section 6* **Welded pressure pipes**

6.1 General

6.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this section unless other more stringent requirements have been specified.

6.1.2 Piping systems are to be constructed in accordance with approved plans and specifications.

6.1.3 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc welding processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel material that is not carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm wall thickness.

6.1.4 Where pressure pipework is assembled and butt welded *in-situ*, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and examination of the joints.

6.2 Fit-up and alignment

6.2.1 Acceptable methods of flange attachment are illustrated in Fig. 1.5.1 in Pt 7, Ch 1. If backing rings are used with flange type (a) then they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

6 2.2 Alignment of pipe butt welds shall be in accordance with Table 3.6.1. Where fusible inserts are used the alignment shall be within 0,5 mm in all cases.

Table 3.6.1 Pipe alignment tolerances

Pipe size	Maximum permitted mis-alignment
D < 150ϕ mm and $t \le 6$ mm	1,0 mm or 25% of t whichever is the lesser
D < 300ϕ mm and $t \le 9{,}5$ mm	1,5 mm or 25% of t whichever is the lesser
$D \ge 300$ and $t > 9{,}5$ mm	2,0 mm or 25% of t whichever is the lesser
$D \equiv$ pipe internal diameter $\underline{T} \equiv$ pipe wall thickness	

6.2.3 Where socket welded fittings are employed they are to comply with the requirements of Pt 7, Ch 1,5.5. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

6.3 Welding workmanship

6.3.1 Welding procedures are to be established for welding of pipework including attachment welds directly to pressure retaining parts and are to be qualified by testing on simulated joints.

6.3.2 Where the work requires a significant number of branch connections, tests may also be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

6.3.3 Welding consumables and, where used, fusible root inserts, are to be suitable for the materials being joined.

6.3.4 For welding of carbon and low alloy steels, preheat is to be applied depending on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 3.6.2 unless welding procedure testing indicates that higher levels are required.

Table 3.6.2 Minimum preheat requirements

Material grade	Thickness t, in mm (4)	Minimum preheat temperature (1), °C	
		Non-low H_2	Low H_2 (2)
Carbon and carbon/manganese grades: 320 and 360	$t \le 10$ $t \ge 20$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \le 10$ $t \ge 20$	75 150	20 100
1Cr 1/2Mo	$t < 13$ $t \ge 13$	(3)	100 150
2 1/4Cr 1Mo	$t < 13$ $t \ge 13$	(3)	150 200
1/2Cr 1/2Mo 1/4V	$t < 13$ $t \ge 13$	(3)	150 200

NOTES
1. For thicknesses up to 6 mm, the preheat levels specified may be reduced subject to satisfactory hardness testing during welding procedure qualification.
   In all cases where the ambient temperature is 0°C or below, preheat is required.
2. Low hydrogen process or consumables are those which have been tested and have achieved a grading of H15 or better, *see* Chapter 11 of Vol 1, Part 2.
3. Low hydrogen process is required for these materials.
4. t = the thickness of the thicker member.

6.3.5 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

6.3.6 All welding is to be performed in accordance with the approved welding procedures (*see* 6.3.1) by welders who are qualified for the materials, joint types and welding processes employed.

6.3.7 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

6.3.8 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

6.3.9 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

6.4 Heat treatment after bending of pipes

6.4.1 Heat treatment should be carried out in a suitable furnace provided with temperature recording equipment in accordance with 5.2.

6.4.2 Hot forming should generally be carried out within the normalizing temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon-manganese steels. For alloy steels, 1Cr 1/2Mo, 2 1/4Cr 1Mo and 1/2Cr 1/2Mo 1/4V, a subsequent stress relieving heat treatment in accordance with Table 3.5.2 is required irrespective of material thickness.

6.4.3 When hot forming is performed outside the normalizing temperature range, a subsequent heat treatment in accordance with Table 3.6.3 is required.

Table 3.6.3 Heat treatment after forming of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalize at 880 to 940°C
1Cr 1/2Mo	Normalize at 900 to 940°C, followed by Tempering at 640 to 720°C
2 1/4Cr 1Mo	Normalize at 900 to 960°C, followed by Tempering at 650 to 780°C
1/2Cr 1/2Mo 1/4V	Normalize at 930 to 980°C, followed by Tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

6.4.4 After cold forming to a radius measured at the centreline of the pipe of less than four times the outside diameter, heat treatment in accordance with Table 3.6.3 is required.

6.4.5 The heat treatments specified above shall be applied unless the pipe material manufacturer specifies or recommends other requirements.

6.4.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

6.5 Post weld heat treatment of pipe welds

6.5.1 Post weld heat treatment shall be carried out in accordance with the general requirements specified in 5.2 for pressure vessels.

6.5.2 Post weld heat treatment is to be performed on steel pipes and fabricated branch pieces on completion of welding where the material thickness exceeds that specified in Table 3.6.4.

Table 3.6.4 Thickness limits for post weld heat treatment of pipe welds

Type of steel	Requirements for heat treatment
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Thicknesses exceeding 30 mm
1Cr $^{1}/_{2}$Mo	Thicknesses exceeding 8 mm
2$^{1}/_{4}$Cr 1Mo	All thicknesses
$^{1}/_{2}$Cr $^{1}/_{2}$Mo $^{1}/_{4}$V	All thicknesses
Other alloy steels	Subject to special consideration

6.5.3 Recommended soaking temperatures and periods for post weld heat treatment are given in Table 3.5.2.

6.5.4 Where oxy-acetylene welding has been used, due consideration should be given to the need for normalizing and tempering after such welding.

■ *Section 7* Non-Destructive Examination

7.1 General

7.1.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognized code or standard.

7.1.2 NDE should not be applied until an interval of at least 48 hours has elapsed since the completion of welding.

7.2 NDE personnel

7.2.1 NDE Personnel are to be qualified to an appropriate level of a nationally recognized certification scheme.

7.2.2 Generally, operators subject to direct supervision are to be qualified to Level I, unsupervised personnel to Level II and more senior personnel to Level III.

7.2.3 Qualification schemes are to include assessments of practical ability for Levels I and II individuals; these examinations to be made on representative test pieces containing relevant defects.

7.3 Extent of NDE

7.3.1 For Class 1 pressure vessels:

(a) All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles over 170 mm outside diameter are subject to 100 per cent volumetric and surface crack detection inspections.

(b) For circumferential butt welds in extruded connections, tubes, headers and other tubular parts of 170 mm outside diameter or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

7.3.2 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. If further unacceptable defects are found then either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated; or

(b) the whole length of the weld represented is to re-examined using the same inspection methods.

7.3.3 Butt welds in Class 1 pipes of 75 mm or more outside diameter are subject to 100 per cent volumetric and surface crack detection inspections. The extent and method of testing applied to butt welds in Class 1 pipes of less than 75 mm outside diameter is at the Surveyor's discretion.

7.3.4 The extent of testing to be applied to butt welds or fillet welds in Class II pipes of 100 mm or more outside diameter is at the Surveyor's discretion.

7.3.5 NDE is not required for Class II pipes less than 100 mm outside diameter.

7.3.6 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure are to be subject to spot volumetric examination, the minimum length of each check point being 300 mm.

7.4 Procedures

7.4.1 Non Destructive Examinations are to be made in accordance with a definitive written procedure prepared in accordance with a nationally recognized standard and endorsed by a Level III individual. As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements.

7.5 Method

7.5.1 Volumetric examinations may be made by radiography or, in the case of welds of nominal thickness 15 mm or above, by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection, and that for non-magnetic materials is liquid penetrant inspection.

7.6 Repairs

7.6.1 Unacceptable defects are to be repaired and re-examined using the NDE methods originally applied.

7.7 Evaluation and reports

7.7.1 The manufacturer shall be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to include the following information where appropriate:

(a) date of inspection;
(b) names, qualifications and signatures of operator and supervisor;
(c) component identification;
(d) location and extent of testing;
(e) heat treatment status;
(f) weld type, procedure and configuration;
(g) surface condition;
(h) inspection procedure reference;
(j) equipment used;
(k) results showing size, position and nature of any defects repaired;and
(l) statement of final acceptability to established criteria.

Section 1 General

1.1 Application

1.1.1 Adequate spare parts for the propelling and essential auxiliary machinery together with the necessary tools for maintenance and repair shall be readily available for use.

1.1.2 The spare parts to be supplied and their location is to be the responsibility of the Navy but must take into account the design and arrangements of the machinery and the intended service and operation of the ship. Account should also be taken of the recommendations of the manufacturers and any applicable requirement of the Naval Authority.

1.2 Tables of spare parts

1.2.1 For general guidance purposes spare parts for main and auxiliary machinery installations are shown in the following Tables:

Table 4.1.1	Spare parts for main oil engines.
Table 4.1.2	Spare parts for auxiliary oil engines.
Table 4.1.3	Spare parts for main steam turbines.
Table 4.1.4	Spare parts for auxiliary steam turbines.
Table 4.1.5	Spare parts for auxiliary air compressors.
Table 4.1.6	Spare parts for boilers supplying steam for propulsion and for essential services.
Table 4.1.7	Spare parts for gas turbines.

Table 4.1.1 **Spare parts for main oil engines** (*see continuation)*

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Main bearings or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1	–
Main thrust block	Pads for one face of Michell type thrust block or Inner and outer race with rollers where roller thrust bearings are fitted	1 set 1	1 set 1
Cylinder liner	Cylinder liner complete with joint rings and gaskets	1	–
Cylinder cover	Cylinder cover, complete with valves, joint rings and gaskets. For engines without covers, the respective valves for one cylinder unit Cylinder cover studs or bolts, with nuts, as applicable for one cylinder	1 $^1/_2$ set	– –
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder Starting air valve, complete with casing, seat, springs and other fittings Relief valve, complete Fuel injection valves of each size and type fitted, complete with all fittings, for one engine *NOTE. Engines with three or more fuel injection valves per cylinder: two fuel injection valves complete per cylinder and a sufficient number of valve parts, excluding the body, to provide, with those fitted, a full engine set	2 sets 1 set 1 1 1 set*	1 set 1set 1 1 $^1/_4$ set
Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set 1 set	– –
Pistons	Crosshead type, piston of each type fitted, complete with piston rod, stuffing box, skirt, rings, studs and nuts Trunk piston type, piston of each type fitted, complete with skirt, rings, studs, nuts, gudgeon pin and connecting rod	1 1	– –
Piston rings	Piston rings, for one cylinder	1 set	–
Piston cooling	Telescopic cooling pipes and fittings or their equivalent, for one cylinder unit	1 set	–

Table 4.1.1 Spare parts for main oil engines (*conclusion*)

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Gear and chain for camshaft drives	Chain drive: separate links with pins and rollers of each size and type fitted	6	–
	Bearing bushes of each type fitted	1 set	–
Cylinder lubricators	Lubricator complete, of the largest size, with its chain drive or gear wheels	1	–
Fuel injection pumps	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valves, springs, etc.)	1	–
Fuel injection piping	High pressure fuel pipe of each size and shape fitted, complete with couplings	1	–
Scavenge blowers (including turbo-chargers)	Rotors, rotor shafts, bearings, nozzle rings and gear wheels or equivalent working parts if of other types NOTE. The spare parts may be omitted where it has been demonstrated at the Enginebuilder's Works, or during sea trials, for an engine of the type concerned, that the engine can be manoeuvred satisfactorily with one blower out of action. The requisite blanking and/or blocking arrangements, applicable for running with one blower out of action as demonstrated, are to be available on board	1 set	–
Scavenging system	Suction and delivery valves for one pump of each type fitted	1 set	–
Reduction and/or reverse gear	Complete bearing bush, of each size fitted in the gearcase assembly	1 set	–
	Roller or ball race, of each size fitted in the gearcase assembly	1 set	–
Main engine-driven air compressors	Piston rings of each size fitted	1 set	–
	Suction and delivery valves complete of each size fitted	$^1/_2$ set	
Gaskets and packings	Special gaskets and packings of each size and type fitted for cylinder covers and cylinder liners for one cylinder	1 set	–

Table 4.1.2 Spare parts for auxiliary oil engines

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Main bearing or shells for one bearing of each size and type fitted, complete with shims, bolts and nuts	1	–
Cylinder valves	Exhaust valves, complete with casings, seats, springs and other fittings for one cylinder	2 sets	–
	Air inlet valves, complete with casings, seats, springs and other fittings for one cylinder	1 set	–
	Starting air valve, complete with casing, seat, springs and other fittings	1	–
	Relief valve, complete	1	–
	Fuel injection valves of each size and type fitted, complete with all fittings, for one engine	$^1/_2$ set	–
Connecting rod bearings	Bottom end bearings or shells of each size and type fitted, complete with shims, bolts and nuts, for one cylinder	1 set	–
	Top end bearings or shells of each size and type fitted, complete with shims, bolts and nuts for one cylinder	1 set	–
	Trunk piston type: gudgeon pin with bush for one cylinder	1 set	–
Piston rings	Piston rings, for one cylinder	1 set	–
Piston cooling	Piston cooling fittings, for one cylinder unit	1 set	–
Fuel injection pumps	Fuel pump complete, or, when replacement at sea is practicable, a complete set of working parts for one pump (plunger, sleeve, valve springs, etc.)	1	–
Fuel injection piping	High pressure fuel pipe of each size and shape fitted, complete with couplings	1	–
Gaskets and packings	Special gaskets and packings of each size and type fitted, for cylinder covers and cylinder liners for one cylinder	1 set	–

Table 4.1.3 Spare parts for main steam turbines

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine	1	–
Turbine thrust	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size for one engine Assorted liners for one block where fitted	1 set	1 set
Main thrust block	Pads for one face of Michell type thrust block or Inner and outer race with rollers where roller thrust bearings are fitted	1 set 1	1 set 1
Turbine shaft sealing rings	Carbon sealing rings, where fitted, with springs, for each size and type of gland, for one engine	1 set	–
Oil filters	Disposable filter elements of each type and size fitted	1 set	–

Table 4.1.4 Spare parts for auxiliary steam turbines

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Main bearings	Complete bearing bush, of each size and type fitted, for the rotor, pinion and gear wheel shafts, for one engine	1	–
Turbine thrust	Pads of each size for one face of Michell type thrust, or rings for turbine adjusting block, of each size for one engine Assorted liners for one block where fitted	1 set	1 set
Turbine shaft sealing rings	Carbon sealing rings, where fitted, with springs, for each size and type of gland, for one engine	1 set	–
Oil filters	Disposable filter elements of each type and size fitted	1 set	–

Table 4.1.5 Spare parts for auxiliary air compressors

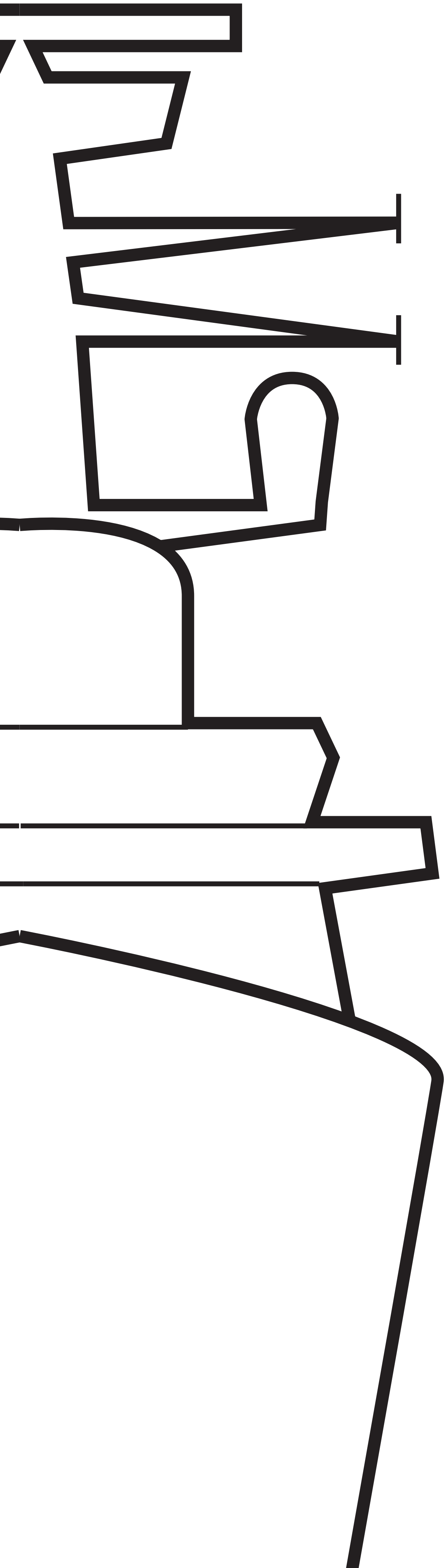
Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Piston rings	Rings, of each size fitted, for one piston	1 set	1 set
Valves	Suction and delivery valves, complete, of each size fitted	$^1/_2$ set	$^1/_2$ set

Table 4.1.6 **Spare parts for boilers supplying steam propulsion and for essential services**

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Tube stoppers or plugs	Tube stoppers or plugs, of each size used, for boiler, superheater and economizer tubes	10	6
Oil fuel burners	Oil fuel burners complete or a complete set of wearing parts for the burners, for one boiler	1 set	1 set
Gauge glasses	Gauge glasses of round type	2 sets per boiler	2 sets per boiler
	Gauge glasses of flat type	1 set for every two boilers	1 set for every two boilers

Table 4.1.7 **Spare parts for gas turbines**

Item	Spare parts	Number	
		Ships for unrestricted service	Ships for restricted service
Reduction gear	Complete bearing bush of each size fitted for the pinion(s) and gear wheel shaft for one turbine	1	—
Oil fuel burners	Oil fuel burners complete or a complete set of wearing parts for the burners, for one turbine	1 set	1 set
Igniters	Full set for one turbine	1 set	1 set
Oil filters	Disposable filter elements of each size and type fitted	1 set	1 set
Oil fuel metering	Fuel metering unit complete	1 set	—
Gas turbine manufacturer's recommended spares for each installation in addition to the above		1 set	1 set



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 2*

Prime movers

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Chapter Contents

Volume 2, Part 2

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Section 1 General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 The requirements of Section 4 do not apply to diesel engines intended for essential services where power does not exceed 110 kW.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent (*see* Pt 10, Ch 1).

1.4 Inclination of ship

1.4.1 Main and essential auxiliary diesel engines are to operate satisfactorily under the conditions as shown in Table 2.4.1 in Pt 1, Ch 2.

1.5 Engine type testing

1.5.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

Section 2 Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted:

Crankshaft assembly plan.
Crankshaft details plan.
Thrust shaft.
Thrust bearing assembly.
Coupling bolts.
Counterweights, where attached to crankthrow.
Main engine holding down arrangement.
Type and arrangement of crankcase explosion relief valves.
Details of the securing and collision arrangements (*see also* Pt 1, Ch 2).
Schematic oil fuel system, including controls and safety devices.
Lubricating oil system.
Starting air system.
Cooling water system.
Control engineering aspects in accordance with Part 9.
Shielding of high pressure fuel pipes.
Longitudinal and transverse cross-section.
Cast bedplate, crankcase and frames.
Cylinder cover, liner and jacket (or engine block).
Piston assembly.
Tie rod.
Connecting rod, piston rod, and crosshead assemblies.
Camshaft drive and camshaft general arrangement.
Shielding and insulation of exhaust pipes.
Details of turbochargers.
Vibration dampers/detuners and moment compensators.
Cross-sectional plans of the assembled turbo-charger with main dimensions.
Fully dimensioned plans of the rotor.
Material particulars with details of welding and surface treatments.
Turbo-charger operating and test data.

2.1.2 The following information and calculations are to be submitted.

Crankshaft design data as outlined in Section 4.
Combustion pressure-displacement relationship.
Power/speed operational envelope.
Calculations and information for short term high power operation where applicable.
Arrangement and welding specifications with details of the procedures for fabricated bedplate, crankcases, frames and entablatures. Details of welding consumables, fabrication sequence and heat treatments are to be included.
Operation and maintenance manuals.
Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.
Arrangement of interior lighting, where provided.
Engine Type test programme, where required including proposals for short term high power operation.
Alternative proposals for hydraulic tests where design features are such that modifications to the test requirements are necessary.

2.1.3 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

2.1.4 For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee's works.

2.1.5 A Failure Mode and Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to include the following associated sub-systems:

Starting and stopping.
Oil fuel.
Lubricating oil.
Cooling water (fresh and sea).
Air induction.
Exhaust.
Engine mounting.
Control and monitoring.
Electrical power supplies.

It is not necessary to consider failure modes relating to the engine components.

2.1.6 Where considered necessary additional documentation may be required.

■ *Section 3* Materials

3.1 Materials test and inspections

3.1.1 Components for engines are to be tested as indicated in Table 1.3.1 and in accordance with the relevant requirements of Volume 1, Part 2, *Rules for the Manufacture, Testing and Certification of Materials*.

3.2 Crankshaft materials

3.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings –
400 to 550 N/mm^2.
(b) Carbon-manganese steel forgings (normalized and tempered) –
400 to 600 N/mm^2.
(c) Carbon-manganese steel forgings (quenched and tempered) –
not exceeding 700 N/mm^2.
(d) Alloy steel castings –
not exceeding 700 N/mm^2.
(e) Alloy steel forgings –
not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings –
370 to 800 N/mm^2.

Table 1.3.1 Material testing requirements

Component	Material tests	Non-destructive tests: Magnetic particle or Liquid penetrant	Non-destructive tests: Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.

■ *Section 4* **Crankshaft design**

4.1 Application

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

4.2 Symbols

4.2.1 For the purposes of this Chapter the following symbols apply (*see also* Fig. 1.4.1):

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (Note: alternating is taken to be $^1/_2$ range value)
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (Note: alternating is taken to be $^1/_2$ range value)
U = pin overlap
α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_p,σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2
σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2.

4.3 Stress concentration factors

4.3.1 **Geometric factors**. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 1.4.1.

Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,20	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$u = U/D_p$	–0,50	0,70

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit u down to –0,7 is acceptable, but for calculation purposes the limit in the above Table applies.

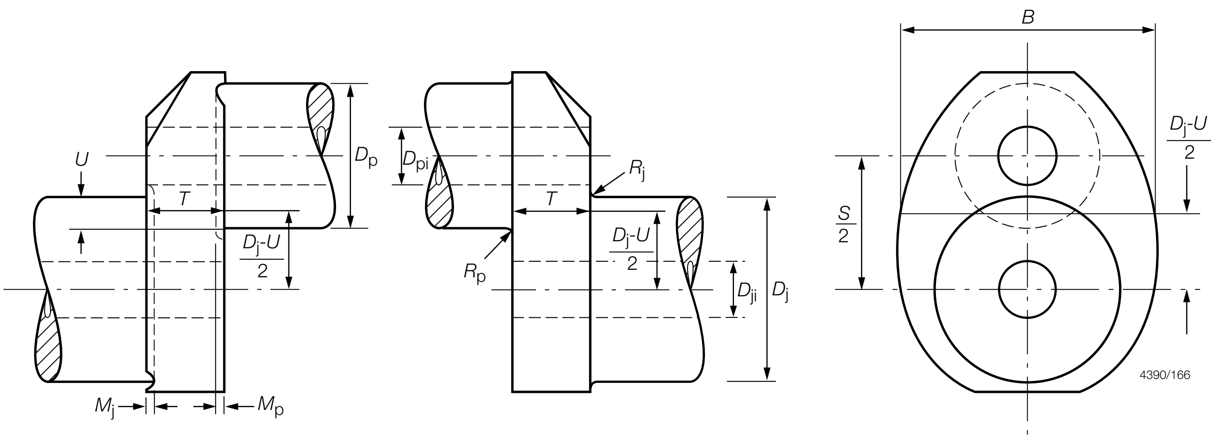


Fig. 1.4.1 Crank dimensions necessary for the calculation of stress concentration factors

4.3.2 Crankpin stress concentration factors:

Bending

α_B = 2,70 $f(ut).\ f(t).\ f(b).\ f(r).\ f(dp).\ f(dj).\ f(rec)$

where

$f(ut)$ = $1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

$f(t)$ = $2{,}18t^{0{,}717}$

$f(b)$ = $0{,}684 - 0{,}0077b + 0{,}147b^2$

$f(r)$ = $0{,}208r_p^{(-0{,}523)}$

$f(dp)$ = $1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

$f(dj)$ = $1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$

Torsion

α_T = $0{,}8\ f(ru).\ f(b).\ f(t)$

where

$f(ru)$ = $r_p^{-(0{,}22 + 0{,}1u)}$

$f(b)$ = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t)$ = $t^{(-0{,}145)}$

4.3.3 Crank journal stress concentration factors:

Bending

β_B = $2{,}71f_B(ut).\ f_B(t).\ f_B(b).\ f_B(r).\ f_B(dj).\ f_B(dp).\ f(rec)$

where

$f_B(ut)$ = $1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

$f_B(t)$ = $2{,}24t^{0{,}755}$

$f_B(b)$ = $0{,}562 + 0{,}12b + 0{,}118b^2$

$f_B(r)$ = $0{,}191r_{jB}^{(-0{,}557)}$

$f_B(dj)$ = $1 - 0{,}644d_j + 1{,}23(d_j)^2$

$f_B(dp)$ = $1 - 0{,}19d_p + 0{,}0073(d_p)^2$

$f(rec)$ = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$

Direct shear

β_Q = $3{,}01f_Q(u).\ f_Q(t).\ f_Q(b).\ f_Q(r).\ f_Q(dp).\ f(rec)$

where

$f_Q(u)$ = $1{,}08 + 0{,}88u - 1{,}52(u)^2$

$$f_Q(t) = \frac{t}{0{,}0637 + 0{,}937t}$$

$f_Q(b)$ = $b - 0{,}5$

$f_Q(r)$ = $0{,}533r_{JB}^{(-0{,}204)}$

$f_Q(dp)$ = $1 - 1{,}19d_p + 1{,}74(d_p)^2$

$f(rec)$ = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

valid only between $u = -0{,}5$ and $0{,}5$

Torsion where

$\beta_T = 0{,}8f(ru).\ f(b).\ f(t)$

$f(ru)$ = $r_{jT}^{(-0{,}22 + 0{,}1u)}$

$f(b)$ = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t)$ = $t^{(-0{,}145)}$

4.3.4 Where experimental measurements of the stress concentrations are available, these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

4.4 Nominal stresses

4.4.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.4.2 Nominal bending stresses are referred to the web bending modulus.

4.4.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \ \text{N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \ \text{mm}^3$$

k_e = 0,8 for crosshead engines

= 1,0 for trunk piston engines.

4.4.4 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 4.4.3.

4.4.5 Nominal stress is referred to the web cross-section area.

4.4.6 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \ \text{N/mm}^3$$

where

A_{web} = BT mm^2

4.4.7 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

4.4.8 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Part 5 are to be submitted.

4.4.9 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \ \text{N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \pi \frac{(D^4 - d^4)}{16D} \ \text{mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_a = \left((18{,}6 - 0{,}0132 D_e) \times \frac{\sigma_u + 160}{560}\right) \times Z_e \quad \text{N/mm}$$

where

$$D_e = D_j \sqrt[3]{1 + \left(\frac{D_{ji}}{D_j}\right)^4}$$

or

$$D_e = D_p \sqrt[3]{1 - \left(\frac{D_{pi}}{D_p}\right)^4}$$

whichever is the smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{(D_e^4 - d^4}{16 D_e} \quad \text{mm}^3$$

4.4.10 Reference should be made to Pt 5, Ch 1 on the calculations of torsional vibration characteristics.

4.4.11 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.5 Maximum stress levels

4.5.1 Crankpin fillet.

Maximum alternating bending stress:

$$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax}) \quad \text{N/mm}^2$$

where

α_B = bending stress concentration (*see* 4.3.2)

Maximum alternating torsional stress:

$$\tau_p = \alpha_T \tau_{ax} \quad \text{N/mm}^2$$

where

α_T = torsional stress concentration (*see* 4.3.2)

τ_a = nominal alternating torsional stress in crankpin N/mm²

4.5.2 Crank journal fillet.

Maximum alternating bending stress:

$$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q \quad \text{N/mm}^2$$

where

β_B = bending stress concentration (*see* 4.3.3)

β_Q = direct stress concentration (*see* 4.3.3)

Maximum alternating torsional stress:

$$\tau_j = \beta_T \tau_a \quad \text{N/mm}^2$$

where

β_T = torsional stress concentration (*see* 4.3.3)

τ_a = nominal alternating torsional stress in main journal N/mm²

4.6 Equivalent alternating stress

4.6.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{epj}\sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \quad \text{N/mm}^2$$

where

σ = σ_p or σ_j N/mm²

τ = τ_p or τ_j N/mm²

4.7 Fatigue strength

4.7.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}\right) \text{N/mm}^2$$

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}}\right) \text{N/mm}^2$$

where

σ_u = UTS of crankpin or crank journal as appropriate, in N/mm²

K_1 = fatigue endurance factor appropriate to the manufacturing process

= 1,05 for continuous grain-flow (CGF) or die-forged

= 1,0 for freedom forged

= 0,93 for cast steel

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.7.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened

= 1,25 for nitrided.

4.8 Acceptability criteria

4.8.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e} \quad \text{for crankpin and journal}$$

where

σ_f = σ_{fp} or σ_{fj}

σ_e = σ_{ep} or σ_{ej}

4.9 Crankshaft oil hole

4.9.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish.

4.9.2 Fatigue strength calculations or alternatively fatigue test results may be required to demonstrate acceptability.

4.10 Shrink fit of semi-built crankshafts

4.10.1 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.10.2 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5(D_s - D_j)$.

4.10.3 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

4.10.4 Deviations from these parameters will be specially considered.

4.10.5 The proposed diametral interference is to be within the following limits (*see also* Fig. 1.4.2):
The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6\,(FoS)}{T\,Ds\,\mu\,E}\;\frac{P}{R}\;(1 + C)\;\frac{k^2 - l^2}{(k^2 - 1)\,(1 - l^2)}\ \text{mm}$$

or

$$\delta_{min} = \frac{\sigma_y\,D_s}{E}$$

where

h = minimum radial thickness of the web around the diameter D_s, mm

$k = \dfrac{D_o}{D_s}$

$l = \dfrac{D_{ji}}{D_s}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the *P/R* rating being considered

D_o = $D_s + 2h$, mm

D_s = shrink diameter, in mm

E = Young's modulus of elasticity of crankshaft material, N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces provided $T/D_s > 0{,}4$

Maximum diametral interference, δ_{max}. is not to be greater than:

$$\delta_{max} = \frac{\sigma_y\,D_s}{E} + \frac{1{,}8D_s}{1000}\ \text{mm}$$

4.10.6 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

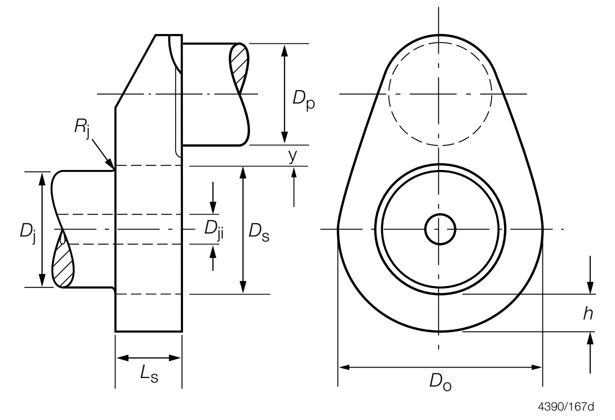


Fig. 1.4.2
Crankthrow of semi-built crankshaft

Section 5
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction and the doors are to be securely fastened so that they will not be readily displaced by an explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of Vol 1, Pt 2, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

■ *Section 6* **Safety arrangements on engines**

6.1 Cylinder relief valves

6.1.1 Cylinder relief valves are to be fitted to engines having cylinders over 230 mm bore. The valves are to be loaded to not more than 40 per cent above the designed maximum pressure and are to discharge where no damage can occur.

6.1.2 In the case of auxiliary engines, consideration will be given to the replacement of the relief valve by an efficient warning device of overpressure in the cylinder.

6.1.3 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Crankcase relief valves

6.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, of an approved type, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed to open at a pressure not greater than 0,2 bar.

6.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.2.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with a standard acceptable to LR. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.2.4 In engines having cylinders not exceeding 200 mm bore and having a crankcase gross volume not exceeding0,6 m^3, relief valves may be omitted.

6.2.5 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.6 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.7 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.8 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.2.9 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.2.10 The free area of each relief valve is to be not less than 45 cm^2.

6.2.11 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.2.12 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

6.3 Vent pipes

6.3.1 Where crankcase vent pipes are fitted, they are to be made as small as practicable to minimize the inrush of air after an explosion. Vents from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.3.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.3.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.4 Warning notice

6.4.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.5 Crankcase access and lighting

6.5.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.5.2 Interior lighting, where fitted, is to be flameproof.

6.6 Emergency operation

6.6.1 Diesel engines and their service systems are to be capable of operation for a period of not less than eight hours when the engine compartment is flooded by seawater to a mean level corresponding to the height of the lowest part of the engines' crankshaft main bearing journals with the ship in the most limiting trim.

■ *Section 7* Starting arrangements

7.1 Initial starting arrangements

7.1.1 Equipment for starting the main and auxiliary engines is to be provided so that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by a hand starting oil engine, except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

7.2 Starting arrangements – Air compressors

7.2.1 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

7.2.2 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

7.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

7.2.4 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

7.2.5 Where starting air is provided from a general use compressed air system, it is to be demonstrated that the system capacities are consistent with the philosophy described in 7.2.1.

7.3 Air receivers

7.3.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Pt 8, Ch 2.

7.3.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.
(b) For all other types of multi-engine installations three consecutive starts per engine are required.

7.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

7.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C.

7.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

7.4 Starting air pipe systems and safety fittings

7.4.1 Air start piping systems are in general to comply with the requirements of Part 7, due regard being paid to the particular type of installation.

7.4.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.7 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

7.4.8 Alternative safety arrangements may be submitted for consideration.

7.5 Electrical starting arrangements

7.5.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 7.3.

7.5.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.5.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.5.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in 7.5.1 and 7.5.3.

7.5.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery change level.

7.5.6 Transient electrical loads due to starting of engines are not to interfere with power supplies to control and weapons systems.

7.5.7 The requirements for battery installations are given in Pt 10, Ch 1.

7.6 Starting of the emergency source of power

7.6.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 0ºC. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.6.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.6.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.

(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energized by the emergency switchboard.

(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.6.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.6.5 When hand (manual) starting is not practicable, the provisions of 7.6.2 and 7.6.3 are to be complied with except that starting may be manually initiated.

7.6.6 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own monitoring arrangements.

■ *Section 8* Piping systems

8.1 General

8.1.1 Diesel engine piping systems are, in general, to comply with the requirements of Pt 7, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 Short lengths of synthetic rubber hoses that comply with the requirements of Pt 7, Ch 1,13 may be used to accommodate relative movement between machinery and fixed piping systems.

8.2 Oil fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 7, Ch 3,3 and 3,4, as applicable.

8.2.2 Means are to be provided to safely purge the oil fuel system of air.

8.2.3 All external high pressure fuel delivery lines between the pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.2.4 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage to collector tank(s) fitted in a safe position and also prevent contamination of lubricating oil by oil fuel. An alarm is to be provided to indicate that leakage is taking place.

8.2.5 Diesel engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. In particular this applies to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised oil fuel leaks.

8.2.6 Where multi-engined installations are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines is to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines, *see also* Pt 1, Ch 2,4.14.

8.2.7 The arrangements of injection pumps, injectors and connections are to be such that leak-off fuel and lubricating oil cannot cross-contaminate each other.

8.3 Oil fuel filters and fittings

8.3.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

8.3.2 Drip trays are to be fitted under oil fuel filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.4 Lubricating oil systems

8.4.1 Lubricating oil arrangements are to comply with the requirements of Part 7 as applicable.

8.4.2 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for special consideration.

8.4.3 The lubrication system for each engine is to be independent from any other engine. A common lubricating oil storage tank arrangement may be provided.

8.4.4 Each engine is to be provided with a means of checking the running and static level of oil in the system/engine.

8.4.5 Means are to be provided to safely purge lubricating oil systems of air.

8.4.6 All vent pipes are to be arranged with a continuous upward slope of at least 10° to prevent the collection of oil in pockets and bends.

8.4.7 Oil sampling arrangements with the ability to take samples when the engine is running are to be fitted with valves or cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.5 Engine cooling water systems

8.5.1 Cooling water arrangements are to comply with the requirements of Part 7, as applicable.

8.6 Intake and exhaust systems

8.6.1 Engine intakes are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmfulparticles.

8.6.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.6.3 Each engine is to have an independent exhaust system.

8.6.4 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.6.5 The design of exhaust systems is to prevent deterioration of engine parts resulting from ingress of sea or rain water via the exhaust ducting when the engine is not in use. Drainage arrangements are to be provided and are to be led to a tank suitable for the potentially corrosive nature of any drainage.

8.6.6 Exhaust systems are not to pass through accommodation spaces.

8.6.7 The exhaust system is to accommodate thermal expansion and movement of the duct due to the combined effects of operating the engines and flexure of the ship's structure.

8.6.8 The exhaust ducting and silencers are to be designed and installed to minimise the risk of unburnt fuel collecting inside the duct.

8.6.9 The design of the exhaust ducting and associated equipment is to minimise the risk of soot collecting at any point other than those specifically intended for soot removal. Inspection and access openings are to be provided.

8.7 High pressure oil systems

8.7.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

8.8 Air induction systems

8.8.1 An air filter is to be fitted at the inlet to each engine. The air filters are to satisfy the following:

(a) Be readily removable for cleaning.
(b) Have an efficiency of not less than 98 per cent at 100 per cent of rated flow capacity when tested to an acceptable standard specified by the manufacturer.
(c) Be provided with an indicator, such as a pressure drop indicator, to indicate when a filter requires cleaning.
(d) Be of a design that does not degrade the performance of the engine.
(e) For engines drawing air from the engine compartment, be as close as possible to the engine air inlet and in such cases the debris screen required by 8.8.4(c) may be omitted.

8.8.2 Where there is a navy requirement to provide a ducted air system to convey air from inlets on deck to the engine the requirements of 8.8.3 to 8.8.6 are to be complied with.

8.8.3 The ducting is to be led by the most direct route practicable consistent with the arrangement of adjacent systems and equipment.

8.8.4 Each ducted air supply is to have the following:

(a) Means to prevent sea spray, aerosol salt and sand reaching the engine and means to remove any such substances that enter the intakes or their bypass arrangements. Suitable drainage arrangements to remove any water from intakes and intake bypass arrangements (where fitted) to guard against the risk of icing are also to be provided.
(b) Means of ensuring that loads are not transmitted from the engine to the ducting, such as a flexible bellows, *see* Pt 7, Ch 1,14.
(c) A debris screen that is easily accessible for cleaning located close to the engine.

8.8.5 The design of induction air systems is to provide a nominal constant air speed that should be as low as reasonably practicable to minimise pressure losses. The inlet pressure drop across the system, including filters and silencers, etc. is not to exceed the engine manufacturer's recommendations.

8.8.6 Air induction system intakes are to be designed and installed such that turbulent flow is not induced therein by ship motions.

■ *Section 9* Control and monitoring

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of Part 9. *See* Pt 1, Ch 2,4 for requirements for operating conditions.

9.1.2 While it is recommended that oil mist monitoring or engine bearing temperature monitors for crankcase protection be fitted, they are in any case to be provided:
(a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure.
(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

NOTES:
1. For medium and high speed engines automatic shutdown of the engine is to occur.
2. For slow speed engines, automatic slowdown is to occur.
3. Where arrangements are made to override the automatic slowdown or shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
4. Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.

9.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Propulsion engine speed governors

9.2.1 An efficient speed governor is to be fitted to each diesel engine that provides mechanical drive to propeller(s) and adjusted so that the speed does not exceed that for which the engine is approved by more than 15 per cent.

9.2.2 Diesel engines coupled to electrical generators that are the source of power for main electric propulsion are to comply with the requirements for electrical generator engines in respect of governors and overspeed protection devices.

9.3 Electrical generator and auxiliary engine speed governors

9.3.1 Diesel engines intended for driving electrical generators are to be fitted with governors which, with fixed setting, are to control the speed within the design limits of the electrical system requirements. Unless otherwise required by the electrical system power supply requirements, the governor is to control the engine speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or, when after run on no load for at least 15 minutes, the load is suddenly applied as follows:
(a) For engines with BMEP less than 8 bar, full load, or
(b) For engines with BMEP greater than 8 bar, 800/BMEP per cent, but not less than one-third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

9.3.2 The no-load stability of governors on electrical generator engines is to be such as to enable satisfactory paralleling to be achieved.

9.3.3 For alternating current installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 9.3.1 are to return and remain within one per cent of the final steady state speed. Where there are no stated electrical power supply requirements for a particular installation, this should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see* Pt 10, Ch 1,1.7.

9.3.4 Emergency generator engines are to comply with 9.3.1 except that the initial load required by 9.3.1(b) is to be not less than the total connected emergency load.

9.3.5 Where the electrical system power supply requirements are to comply with STANAG 1008 and the electrical class notation **ELS** is required, the requirements in 9.3.6 to 9.3.8 are also applicable. Alternative performance characteristics may be accepted where transient stability analysis required by Pt 10, Ch 1,1.8 has been submitted for consideration and accepted by Lloyd's Register (hereinafter referred to as 'LR').

9.3.6 The cyclic irregularity of the engine speed is not to exceed 0,25 per cent where cyclic irregularity is defined as:

> The ratio of the difference between the maximum and minimum instantaneous angular velocity at the flywheel during one engine cycle to the mean speed when the engine is running at any load up to and including rated load and at rated speed.

9.3.7 The performance of mechanical governors is to be such that the engine steady state speed change from no load to rated load and vice versa required by 9.3.1 is between 3,5 and 4 per cent of the nominal speed. The rate of change of speed with change of load is to be not less than 0,4 times the average rate from no load to full load. For load changes of 25 per cent of the rated load, the momentary speed change is not to exceed 2,5 per cent of the nominal speed; and the speed is to remain within 1 per cent of the final steady state speed in not more than 2 seconds from the instant of load change.

9.3.8 The performance of electronic governors is to be such that the engine steady state speed change from no load to rated load and vice versa required by 9.3.1 is between 0,875 and 1 per cent of the nominal speed. The rate of change of speed with change of load is to be not less than 0,4 times the average rate from no load to full load. For load changes of 25 per cent of the rated load, the momentary speed change is not to exceed 2,5 per cent of the nominal speed; and the speed is to remain within 0,2 per cent of the final steady state speed in not more than two seconds from the instant of load change.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 9.4 or 9.5 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 9.1 to 9.8 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 1.9.1(a) and (b) and 1.9.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.3 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.6.4 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.7 Diesel engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in 9.7.2 to 9.7.7 and Tables 1.9.1(a) and (b). *See also* 9.1.2 and 9.6.3.

Table 1.9.1(a) Diesel engines for propulsion purposes: Alarms and slowdowns
(*See continuation*)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*	1st stage Low	Engines (and gearing if fitted). Slowdown
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Oil mist concentration in crankcase or bearing temperature	High	Automatic slowdown of slow speed engines, *see* 9.1.2
Cylinder lubricator flow	Low	One sensor per lubricator unit. Slowdown (automatic on medium and high speed engines)
Thrust bearing temperature*	High	Slowdown
Piston coolant inlet pressure	Low	If a separate system. Slowdown
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slowdown
Piston coolant outlet flow*	Low	Per cylinder (if a separate system). Slowdown
Cylinder coolant inlet pressure or flow*	Low	Slowdown (automatic on medium and high speed engines)
Cylinder coolant outlet temperature*	1st stage high	Per cylinder (if a separate system) Slowdown (automatic on medium and high speed engines)
Engine cooling water system –oil content	High	Where engine cooling water used in heat exchangers
Sea-water cooling pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Oil fuel high pressure piping*	Leakage	*See* 9.6.3
Charge air cooler outlet temperature	High and Low	4-stroke medium and high speed engines
Scavenge air temperature (fire)	High	Per cylinder, (2 stroke engines). Slowdown
Scavenge air receiver water level	High	—

Table 1.9.1(a) Diesel engines for propulsion purposes: Alarms and slowdowns (*conclusion*)

Item	Alarm	Note
Exhaust gas temperature*	High	Per cylinder. Slowdown (automatic on medium and high speed engines)
Exhaust gas temperature deviation from average*	High	Per cylinder, for engine power >500 kW/cylinder. *See* Note 5
Turbocharger exhaust gas inlet temperature	High	Each turbocharger
Turbocharger exhaust gas outlet temperature*	High	Each turbocharger
Turbocharger lubricating oil inlet pressure	Low	If system not integral with turbocharger
Turbocharger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbocharger
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	—
Direction of rotation	Wrong way	Reversible engines, *see also* 9.7.7
Overspeed*	High	*See also* 9.4
Automatic start of engine	Failure	*See* 9.7.7
Electrical starting battery charge level	Low	—

NOTES
1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less only the items marked * are required.
3. Common sensors are acceptable for alarms and slowdown functions.
4. Except where stated otherwise in the Table, slowdown may be effected by either manual or automatic means, by reduction of speed or power as appropriate.
5. For engine powers <500 kW/cylinder, but total power >500 kW, a common sensor for exhaust gas manifold temperature is to be fitted.

9.7.2 Alarms are to operate for the fault conditions shown in Table 1.9.1(a). Where applicable, indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

9.7.3 Alarms are to operate, and automatic shutdown of machinery is to occur for the fault conditions shown in Table 1.9.1(b).

Table 1.9.1(b) Diesel engines for propulsion purposes: Alarms and shutdowns

Item	Alarm	Note
Lubricant oil inlet pressure	2nd stage low	Automatic shutdown of engines (and gearing if fitted), *see* 9.6.2
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of medium and high speed engines, *see* 9.1.2
Cylinder coolant outlet temperature	2nd stage high	Automatic shutdown of medium and high speed engines, *see* 9.6.2

Table 1.9.2 Auxiliary diesel engines: Alarms and shutdowns

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
	2nd stage low*	Automatic shutdown of engine*, *see* 9.6.2
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of engine, *see* 9.1.2
Oil fuel high pressure piping*	Leakage	See 9.1.2
Coolant outlet temperature (for engines >220 kW)	1st stage high	—
	2nd stage high*	Automatic shutdown of engine*, *see* 9.6.3
Coolant pressure or flow	Low	—
Oil fuel temperature or viscosity	High and Low	Heavy oil only
Overspeed	High	*See* 9.4
Starting air pressure	Low	—
Electrical starting battery charge level	Low	—
Exhaust gas temperature	High	Per cylinder for engine power >500 kW/cylinder *See* Note 1

NOTES
1. For engine powers <500 kW/cylinder, but total power >500 kW, a common sensor for exhaust gas manifold temperature is to be fitted.
2. There are no classification requirements for the items marked * in the case of engines being used for the emergency source of electrical power.
3. The arrangements are to comply with the requirements of the Naval Authority concerned.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.

9.7.5 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

9.7.6 The number of automatic consecutive attempts which fail to produce a start are to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 7.5.

9.7.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in Table 1.9.2. *See also* 9.1.2 and 9.6.3.

9.8.2 For engines operating on heavy oil fuel, automatic temperature of viscosity controls are to be provided.

■ *Scope*

The requirements of this Chapter are applicable to gas turbines for main propulsion and also, where powers exceed 110 kW (150 shp), to those for essential auxiliary services. The requirements do not apply to exhaust gas turbo-blowers.

Approval will be in respect of the mechanical integrity of the gas turbine (including gas generator and power turbine), intake and exhaust ducting configuration, acoustic enclosure configuration (where appropriate), fuel, lubricating oil and starter systems, control alarm and monitoring systems and other critical support systems.

Type approval of the gas turbine bare engine will be required as part of the approval process for first of type.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with Pt 1, Ch 1 and Ch 2, *General Requirements for Machinery and Engineering Systems*.

1.2 Standard reference conditions

1.2.1 Where power, efficiency, heat rate or specific consumption refer to standard conditions (ISO 2314), such conditions are to be:

(a) for the intake air at the compressor flange (compressor intake flare):
- a total pressure of 101,3 kPa;
- an ambient temperature of 15°C;
- a relative humidity of 60 per cent; and

(b) for the exhaust at the turbine exhaust flange (or recuperator outlet):
- a static pressure of 101,3 kPa.

1.3 Power ratings

1.3.1 Where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values are those defined in Pt 1, Ch 2,4.3.

1.4 Gas turbine type approval

1.4.1 New gas turbine types or developments of existing types are to be type approved in accordance with Lloyd's Register's (hereinafter referred to as 'LR') *Type Approval System Procedure – Test Specification GT98*.

1.4.2 Where a gas turbine type has subsequently proved satisfactory in service with a number of applications, a maximum power uprating of 10 per cent may be considered without a further complete design re-assessment and type test.

1.5 Inclination of vessel

1.5.1 Gas turbines are to operate satisfactorily under the conditions of inclinations as shown in Table 2.4.1 in Pt 1, Ch 2.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 An engineering description of the gas turbine, including references to plans required in 2.1.2, is to be submitted so that the function of all essential and safety critical components and systems necessary for the turbine operation are clearly defined.

2.1.2 To assess compliance with the design requirements of the Rules and for inspection, installation and record purposes, the following plans are to be submitted for consideration:
- Casing construction arrangement.
- Arrangements of combustion chambers, intercoolers and heat exchangers.
- Compressor and gas generator rotating components.
- Control engineering systems, *see* Pt 9, Ch 1.
- Cooling and sealing air arrangements for compressor and gas generator components: Schematic only.
- Cooling water system: Schematic only.
- Gas turbine unit acoustic enclosure, if applicable, including ventilation and drainage systems: Schematic only.
- Inlet and exhaust ducting arrangement.
- Lubricating oil systems: Schematic only.
- Nozzles, blades and blade attachments.
- Oil fuel systems: Schematic only.
- Power turbine components.
- Rotors, bearings and couplings.
- Section assembly.
- Starting system: Schematic only.
- Air bleed system: Schematic only.

- Details of materials of all load bearing and torque transmitting components and pressure retaining parts.
- Details of materials for rotors and discs are to be submitted for approval.

2.1.3 An engineering and safety justification for the turbine, stating design standards and assumptions and providing technical evidence, is also to be submitted. This is to include, but not be limited to:

- Possible failure modes of internal engine components, to include such items as rotors, discs, seals, bearings and coupling, etc., and measures adopted to mitigate such failures that may have an effect on the internal machinery or the surrounding environment/structures/ systems, taking due account of suitability of materials and the effects of stress raisers, etc.
- Limiting operating parameters.
- Short-term high power operation.
- Details of mounting and securing arrangements.
- Rotor and blade vibratory characteristics.

2.1.4 A Failure Mode and Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water.
- Intercooler, where applicable.
- Air induction.
- Exhaust.
- Recuperator, where applicable.
- Gas turbine mounting.
- Control and monitoring.
- Electrical power supplies.

It is not necessary to consider failure modes relating to the gas turbine components for the purposes of this clause.

2.1.5 Miscellaneous. Details of the following are also to be submitted:

- Operation and maintenance manuals including declared lives of critical components and overhaul schedules recommended by the manufacturer.
- Design standard of intake filtration for water particulate and corrosive marine salts.
- Details of compressor washing system.
- Fuel specification.

2.1.6 Details of proposed welding procedures and proposals for routine examination of joints by non-destructive means are to be submitted for consideration.

2.1.7 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration and are to include details of rotor balancing techniques, methods of determining the integrity of pressure casings and heat exchanger tests, *see* Section 1.

2.1.8 The gas turbine manufacturer's requirements for air inlet filters, air intake and uptake arrangements are to be submitted for consideration.

2.1.9 Where a gas turbine installation includes components having a specified life in terms of operating time or operating cycles, or where life is derived from a declared acceptance criteria, details are to be submitted for consideration. Details of proposed arrangements for monitoring life progression are also to be submitted for consideration.

■ *Section 3* Materials

3.1 Material tests and inspection

3.1.1 Components are to be tested in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials (Part 2)).

3.1.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design and construction

4.1 General

4.1.1 All parts of compressors, turbines, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Provision is to be made to limit the distortion of the casing and rotor under all normal operating conditions.

4.1.2 Gas generator and power turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 The turbine installation is to be designed and manufactured to ensure that there are no critical speeds within the operating range.

4.2.2 Vibration monitoring is to form an integral part of the gas turbine safety and control system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shutdown the gas turbine, before an over-critical situation occurs, i.e. multiple rotor blade or disc release.

4.3 Containment

4.3.1 Gas turbines and power turbines are to be designed and installed, so far as is practicable, to contain debris in the event of rotor blade release.

4.3.2 In the event of a major component failure, when the engine casing may not contain the debris; oil fuel, lubricating oil and other potentially hazardous systems or equipment are, where practicable, to be located outside of the plane of high speed rotating parts. Where this is not possible they are to be suitably protected. This requirement also applies to fire detection and extinction equipment, *see also* Section 5.

4.3.3 Gas turbine ancillaries containing flammable products are to be segregated or protected from high temperature areas.

4.4 Intake and exhaust ducts

4.4.1 The air intakes and uptakes are to be in accordance with the turbine manufacturer's design requirements. Particular attention is drawn to the requirements on flow conditions to be achieved throughout the intake and uptake systems. Arrangements are to comply with 4.4.2 to 4.4.8 as applicable.

4.4.2 Air intakes are to be designed and located to minimize the possibility of ingestion of harmful objects. Means are also to be provided for detecting and preventing icing up of air intakes.

4.4.3 Suitable intake filtration is to be provided to control the ingestion of water, particulate and corrosive marine salts within the gas turbine manufacturer's specified limits.

4.4.4 Where an air intake enclosure forms the connection between the ship's downtake and the gas turbine installation, a suitable alarm function is to be provided to give warning when an unacceptable air intake pressure loss is reached at the air inlet (bellmouth) of the gas turbine.

4.4.5 Intakes are to be designed such that material cannot become detached due to air flow or corrosion. Fixing bolts and fastenings are to be positively locked so that they cannot work loose.

4.4.6 Multi-engine installations are to have separate intakes and exhausts so arranged as to prevent induced circulation through a stopped gas turbine unit.

4.4.7 The arrangement of the exhaust duct is to be such as to prevent, under normal conditions of ship motion and atmospheric conditions, exhaust gases being drawn into machinery spaces, air conditioning systems and intakes.

4.4.8 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back into the gas turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion-resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end with suitable arrangements made to prevent water flooding the machinery space.

4.4.9 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

4.5 External influences

4.5.1 Pipes and ducting connected to casings are to be so designed that they apply no excessive loads or moments to the compressors and turbines.

4.5.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.5.3 Where the gas turbine seating incorporates a tank structure, any temperature variation of the tank in service is not to adversely affect the gas generator and power turbine alignment.

4.5.4 For machinery fastening arrangements, including resilient mounting, *see* Pt 1, Ch 2.

4.6 Corrosive deposits

4.6.1 Means are to be provided for periodic removal of salt deposits and atmospheric contaminants from blading and internal surfaces.

4.7 Acoustic enclosures

4.7.1 Where gas turbines are installed in acoustic enclosures, the arrangements are to comply with Pt 1, Ch 2,5.11.

4.8 Thermal insulation

4.8.1 Where surfaces of the gas generator, power turbine and exhaust volute exceed a temperature of 220°C during operation, these are to be suitably insulated and clad to minimize the risk of fire and prevent damage by heat to adjacent components, *see* 5.1.5.

4.9 Welded construction

4.9.1 Full strength welds are to be used for all major joints and be designed so as to ensure complete fusion of the joint.

4.9.2 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of all welding.

4.10 Emergency operation

4.10.1 Gas turbines and their service systems are to be capable of operation for a period of not less than eight hours when the compartment is flooded to the level of the underside of the lowest exposed portion of the gas turbine casing.

■ *Section 5* Piping systems

5.1 General

5.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 7, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

5.1.2 The gas turbine design and construction is to minimize the possibility of a fire fed by fuel or lubricating oil leaks.

5.2 Oil fuel systems

5.2.1 Oil fuel arrangements are to comply with the requirements of Pt 7, Ch 3,3.10.

5.2.2 All external high pressure oil fuel delivery lines between the pressure fuel pumps and fuel metering valves are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings.

5.2.3 Suitable arrangements are to be made for draining any oil fuel leakage from the protection required by 5.2.2 and to prevent contamination of the lubricating oil by oil fuel. An alarm is to be provided to indicate that leakage is taking place.

5.3 Lubricating oil systems

5.3.1 Lubricating oil arrangements are to comply with the requirements of Pt 7, Ch 3,8.

5.3.2 Where the lubricating oil for gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. At least two filters are to be fitted in the lubricating oil supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered lubricating oil to the gas turbine.

5.4 Cooling systems

5.4.1 Cooling water arrangements are to comply with the requirements of Pt 7, Ch 3, as applicable.

5.5 Air bleed systems

5.5.1 Where specified in the operational requirements, provision is to be made for bleeding air from the compressor section in accordance with the design statement. Any open-ended air bleed arrangements are to be led to the uptake or atmosphere and not into the machinery space.

■ *Section 6* Starting arrangements

6.1 General

6.1.1 Equipment for initial starting of gas turbines is to be provided and arranged such that the necessary initial charge of starting air, hydraulic or electrical power can be developed on board the ship without external aid. If, for this purpose, an emergency air compressor or electric generator is required, these units are to be power-driven by manually-started oil engines, except in the case of small installations where a hand-operated compressor of approved capacity may be accepted.

6.1.2 Alternatively, other devices of approved type may be accepted as a means of providing the initial start.

6.1.3 Where the integrity of the starting system is susceptible to overspeed conditions, appropriate alarm and/or trip functions are to be provided.

6.2 Purging before ignition

6.2.1 Means are to be provided to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting, the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided to satisfy the plant air start requirements. For scantlings and fittings of air receivers, *see* Pt 8, Ch 2.

6.3.2 For multi-engine installations, three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where the gas turbine is fitted with electric starters powered from batteries, two batteries are to be fitted. Each battery is to be capable of starting the gas turbine and the combined capacity is to be sufficient without recharging to provide the number of starts required by 6.3.1 or 6.3.2.

6.4.2 The requirements for battery installations are given in Pt 10, Ch 1.

6.5 Hydraulic starting

6.5.1 Where the gas turbine is arranged for hydraulic starting, the capacity of the power pack is to be sufficient to provide the number of starts of the gas turbine as required by 6.3.1 or 6.3.2.

■ *Section 7* Control, alarm and safety systems

7.1 General

7.1.1 Control, alarm and safety systems are to comply with the requirements of this Section and Pt 9, Ch 1. *See* Pt 1, Ch 2,4 for requirements for operating conditions.

7.2 Overspeed protection and shutdown system

7.2.1 The gas turbine is to be protected against overspeed by the provision of a suitable device(s) capable of shutting-down the gas turbine safely before a dangerous overspeed condition occurs.

7.3 Speed governors

7.3.1 A means of controlling the output shaft speed of the gas turbine is to be provided as detailed in 7.3.2 to 7.3.7.

7.3.2 An efficient speed governor independent of the overspeed protective device, is to be fitted to each gas turbine that provides mechanical drive to propeller(s) and adjusted so that the speed does not exceed that which brings the overspeed protective device into action.

7.3.3 Where the gas turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed settings, is to control the turbine speed within the design limits of the electrical system requirements. Unless otherwise required by the electrical system power supply requirements, the governor is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

7.3.4 The no load stability of governors on electrical generator gas turbines is to be such as to enable satisfactory parallelling to be achieved.

7.3.5 Where the electrical system power supply requirements are to comply with STANAG 1008 and the electrical class notation **ELS** is applicable, the requirements of 7.3.6 or 7.3.7 are also applicable. Alternative performance characteristics may be accepted where a transient stability analysis required by Pt 10, Ch 1,1.8 has been submitted for consideration and accepted by LR.

7.3.6 The performance of mechanical governors is to be such that the turbine steady state speed change from no load to rated load and vice versa required by 7.3.3 is between 3,5 and 4 per cent of the nominal speed. The rate of change of speed into change of load is to be not less than 0,4 times the average rate from no load to full load. For load changes of 25 per cent of the rated load, momentary speed change is not to exceed 2,5 per cent of the nominal speed; and the speed is to remain within 1 per cent of the final steady state speed in not more than two seconds from the instant of load change.

7.3.7 The performance of electronic governors is to be such that the turbine steady state speed change from no load to rated load and vice versa required by 7.3.3 is between 0,875 and 1 per cent of the nominal speed. The rate of change of speed with change of load is to be not less than 0,4 times the average rate from no load to full load. For load changes of 25 per cent of the rated load, the momentary speed change is not to exceed 2,5 per cent of the nominal speed; and the speed is to remain within 0,2 per cent of the final steady state speed in not more than two seconds from the instant of load change.

7.4 Power turbine inlet over-temperature control

7.4.1 The power turbine is to be protected against overtemperature by the provision of a suitable device(s) capable of controlling the temperature within acceptable limits or shutting-down the gas turbine safely to prevent damage.

7.5 Flameout

7.5.1 Indication is to be provided for identifying poor combustion from each combustion chamber, flame out and failure to ignite conditions, *see also* 6.2.1.

7.6 Lubricating oil system

7.6.1 Means are to be provided to accurately determine the pressure and temperature of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems to ensure safe operation.

7.6.2 Means are to be provided to ensure that the temperature of the lubrication oil supply is automatically controlled to maintain steady-state conditions throughout the normal operating range of the gas turbine.

7.6.3 Where the oil supply to the power turbine is fed from a separate supply system similar arrangements to those detailed above are to be provided.

7.7 Stopping of gas turbines

7.7.1 Means are to be provided, at both the local and remote control/operating positions, to manually initiate the shutdown of the gas turbine in an emergency.

7.7.2 In addition to 7.7.1, a means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station where the station is remote from the gas turbine control/operating position.

7.7.3 *See also* Pt 1, Ch 1,4.1.1 for requirements for stopping machinery from a position outside the compartment where the machinery is located.

7.8 Indication of temperature

7.8.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

7.9 Automatic and remote controls

7.9.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require manual intervention by the operators, they are required to be provided with alarm and safety arrangements required by 7.9.2 and Table 2.7.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

7.9.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.

(b) Exhaust gas.

7.9.3 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in Table 2.7.1, the sensors and circuits utilized for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

Table 2.7.1 Gas turbine machinery: Alarms and shutdowns

Item	Alarm	Note
Overspeed	High	Automatic shutdown, *see also* 7.2
Power turbine inlet temperature	1st stage high	Automatic power reduction
See Note 4	2nd stage high	Automatic shutdown, *see also* 7.4
Flame failure	Failure	Automatic shutdown, *see also* 7.5
Failure to ignite	Failure	Automatic shutdown, *see also* 7.5
Lubricating oil pressure	1st stage low	—
	2nd stage low	Automatic shutdown, *see also* 7.6
Lubricating oil temperature	High	*See also* 7.6
Lubricating oil filter differential pressure	High	—
Scavenge oil temperature	Low	Automatic shutdown
Scavenge oil pressure	High	—
Bearing temperature		
Turbine vibration	1st stage high	—
	2nd stage high	Automatic shutdown, *see also* 4.2
Oil fuel supply pressure	Low	—
Oil fuel supply temperature	High	—
Oil fuel leakage	High	*See also* 5.2
Automatic starting	Failure	Automatic shutdown
Control system	Failure	Automatic shutdown
Air intake pressure	Low	*See also* 4.4

NOTES
1. For two-stage alarms, *see also* 7.9.3.
2. For requirements on purging before ignition, *see* 6.2.1.
3. Where there are separate lubricating oil systems for gas generator and power turbine/gearing sections, each system is to be monitored.
4. Where there is more than one combustion chamber, the temperature of each chamber is to be monitored.

■ *Section 8* Planned maintenance and condition monitoring procedures, and 'upkeep by exchange'

8.1 Planned maintenance approach

8.1.1 Suitable gas turbine installation Planned Maintenance and Condition Monitoring Schemes (PMS(CM)) will be accepted a part of LR's Continuous Survey Machinery (CSM) cycle provided the principles defined in 8.2 to 8.4 are satisfied.

8.2 Preventive maintenance

8.2.1 Preventive maintenance requires items to be opened out for inspection and overhaul at specified time periods or after a specified number of running hours.

8.2.2 Maintenance is normally carried out irrespective of the condition of the gas turbine in order to retain it in a satisfactory operational condition.

8.3 Unscheduled maintenance

8.3.1 The planned maintenance scheme is to be capable of dealing effectively with breakdown or corrective maintenance, i.e. unscheduled maintenance.

8.4 Condition monitoring

8.4.1 Condition monitoring requires the use of instrumentation to make regular or continuous measurements of certain parameters, in order to indicate the physical state of the gas turbine, without disturbing its normal operation.

8.4.2 The data collected is to be used to determine the actual condition of the gas turbine at any given time or, based on the trend characteristics of the condition, used for predicting the remaining useful life before complete deterioration or loss of performance terminates its ability to carry out its required function.

8.5 Condition monitoring techniques

8.5.1 The conditioning monitoring techniques, to support the trend away from preventive maintenance, listed in Table 2.7.1 are considered the minimum acceptable to obviate the need for a fully opened out inspection of engine components at Periodical Survey.

8.5.2 Alternative arrangements to those in Table 2.8.1, which provide an equivalent level of confidence in the condition of the gas turbine installation, will be considered.

8.6 Upkeep by exchange

8.6.1 Where the gas turbine is maintained using an 'upkeep by exchange' policy, details of the system are to be submitted to LR for approval.

Table 2.8.1 Condition monitoring techniques

Method	Requirement
Visual inspection	Periodic inspection of intakes and exhaust ducts, inlet guide vanes, compressor 1st stage, compressor and gas generator casings and auxiliary components and systems. The running clearances and dimensional changes, where practicable
Visual inspection by borescope/endoscope	Periodic inspection of compressor stators, guide vanes and blades, combustion chambers, turbine nozzles and blades and power turbine
Vibration monitoring	Continuous monitoring and trend analysis of gas generator and power turbine rotor vibration. The equipment used for vibration measurement should be capable of determining vibration throughout the operating range of the gas turbine
Lubrication, oil trend analysis programme	• Periodic inspection of magnetic particle detectors (manual records and/or automatic recording via debris counters in oil scavenge lines) • Periodic inspection of oil filters • Periodic sampling and laboratory analysis of lubricant quality
Fuel quality	• Maintenance of oil fuel bunker/marine gas oil analysis records • Periodic sampling and laboratory analysis of fuel quality
Performance monitoring	Continuous monitoring and trend analysis of critical gas turbine operating parameters including: • Compressor conditions (inlet and exit temperature, delivery pressure and speed) • Power turbine (inlet entry temperature and speed) • Engine breather temperature • Low cycle fatigue counter *See* Note
NOTE Manual recording and trend analysis methods may also be acceptable.	

8.6.2 Where an 'upkeep by exchange' system has been approved, details of units that can be changed independently of each other are not required to be submitted provided there have been no changes since the original approval. The manufacture and testing of the replacement units is to be in accordance with relevant Rule requirements.

8.6.3 Records of each 'upkeep by exchange' are to be kept on board the ship and LR Surveyors are to witness running tests on load after each exchange. A record history is to be maintained for each exchange unit in the engine logbook.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 The requirements of this Chapter are applicable to steam turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Power conditions for generator sets

1.3.1 Auxiliary steam turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent (*see* Pt 10, Ch 1).

1.4 Inclination of ship

1.4.1 Main and essential auxiliary steam turbines are to operate satisfactorily under the conditions as shown in Table 2.4.1 in Pt 1, Ch 2.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 The following plans are to be submitted for consideration, together with particulars of materials, maximum shaft powers and revolutions per minute. The pressures and temperatures applicable at maximum shaft power and under the emergency conditions of 5.2 are to be stated or indicated on the plans:
- General arrangement.
- Sectional assembly.
- Rotors and couplings.
- Casings.

2.1.2 For the emergency conditions of 5.3, full particulars of the means proposed for emergency propulsion are to be submitted.

2.1.3 Where rotors and castings are of welded construction, details of the welded joints are also to be submitted for consideration.

2.1.4 In general, plans for auxiliary turbines need not be submitted.

■ *Section 3* Materials

3.1 General

3.1.1 In the selection of materials, consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

3.1.2 Grey cast iron is not to be used for temperatures exceeding 260°C.

3.2 Materials for forgings

3.2.1 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2.

3.2.2 For alloy steels, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.2.3 When it is proposed to use material of higher tensile strength, full details are to be submitted for approval.

■ *Section 4* Design and construction

4.1 General

4.1.1 In the design and arrangement of turbine machinery, adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimizing casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings and steam pipes. Drainage openings and drain pipes from oil baffle pockets are to be sufficiently large to prevent excessive accumulation and leakage of oil.

4.2 Welded components

4.2.1 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding to equivalent standards, for rotors and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 welded pressure vessels, *see* Pt 1, Ch 3.

4.2.2 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

4.2.3 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc., are to be of welding quality.

4.2.4 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with particulars of the welding consumables, an outline of the welding procedure, method of fabrication and heat treatment, are to be submitted for consideration.

4.2.5 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

4.2.6 Adequate preheating is to be employed for mild steel cylinders and components and where the metal thickness exceeds 44 mm, and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

4.2.7 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. For details of stress relief procedure, temperature and duration, *see* Pt 1, Ch 3,5.2.

4.2.8 The heat treatment of welded rotors is to be carried out as approved.

4.2.9 Surveyors are to be satisfied that the desired quality of welding is attainable with the proposed welding equipment and procedure, and for this purpose test specimens representative of the welded joints are to be provided for radiographic examination and mechanical tests.

4.2.10 For cylinders, the mechanical tests of butt joints are to include tensile, bend and macro-tests as detailed in Pt 1, Ch 3.

4.2.11 For diaphragms, nozzle plates, etc., representative samples are to be sectioned and macro-etched.

4.2.12 For rotors, the mechanical tests are to include tensile (all weld metal), tensile (joint), bend (transverse), bend (longitudinal) and macro-tests as detailed in Pt 1, Ch 3, or such other tests as may be approved.

4.2.13 In subsequent production, check tests of the quality of the welding are to be carried out at the discretion of the Surveyors.

4.3 Stress raisers

4.3.1 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces, and tenons are to be radiused at their junction with blade tips. Balancing holes in discs are to be well rounded and polished.

4.3.2 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands, and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined, and pull-off tests made if considered necessary by the Surveyors.

4.4 Shrunk-on rotor discs

4.4.1 Main turbine rotor discs fitted by shrinking are to be secured with keys, dowels or other approved means.

4.5 Vibration

4.5.1 Care is to be taken in the design and manufacture of turbine rotors, rotor discs and blades to ensure freedom from undue vibration within the operating speed range. Consideration of blade vibration should include the effect of centrifugal force, blade root fixing, metal temperature and disc flexibility where appropriate.

4.5.2 For the vibration and alignment of main propulsion systems formed by the turbines geared to the line shafting, *see* Pt 5, Ch 4.

4.6 External influences

4.6.1 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporate a tank structure, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.7 Steam supply and water system

4.7.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

4.8 Turning gear

4.8.1 The turning gear for all propulsion turbines is to be power-driven and if electric, is to be continuously rated.

■ *Section 5*
Emergency arrangements

5.1 Lubricating oil failure

5.1.1 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure; however, steam is to be made available at the astern turbine for braking purposes in such an emergency. *See* Pt 7, Ch 3 for emergency oil supply.

5.1.2 Auxiliary turbine arrangements are to be such that steam supply is automatically shut off in the event of failure of the lubricating oil pressure.

5.2 Single screw ships

5.2.1 In single screw ships fitted with compound main turbine installations in which two or more turbines are separately coupled to the same main gear wheel, the arrangements are to be such that steam can be led direct to the L.P. turbine and either the H.P or I.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

5.3 Single main boiler

5.3.1 Ships intended for unrestricted service, fitted with steam turbines and having a single main boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

■ *Section 6*
Piping systems

6.1 General

6.1.1 Steam turbine piping systems are, in general, to comply with the requirements given in Pt 7, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

6.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in condensate and lubricating oil systems. *See also* Pt 7, Ch 1.

6.2 Lubricating oil systems

6.2.1 Lubricating oil arrangements are to comply with the requirements of Pt 7, Ch 3.

6.2.2 Where the lubricating oil for main propelling steam turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

6.3 Cooling systems

6.3.1 Cooling water arrangements are to comply with the requirements of Pt 7, Ch 3, as applicable.

6.4 Bled steam connections

6.4.1 Non-return or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

6.5 Steam strainers

6.5.1 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manoeuvring valves.

■ *Section 7* Control and monitoring

7.1 General

7.1.1 Control engineering systems are in general to comply with the requirements of Pt 9, Ch 1.

7.2 Overspeed protective devices

7.2.1 An overspeed protective device is to be provided for main and auxiliary turbines to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

7.2.2 Where two or more turbines of a compound main turbine installation are separately coupled to the same main gear wheel, and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manoeuvring platform.

7.3 Speed governors

7.3.1 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the overspeed protective device is to be fitted, and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

7.3.2 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of alternating current machines intended for parallel operations are to equalize within a tolerance of ± 0,5 per cent.

7.4 Low vacuum and overpressure protective devices

7.4.1 Sentinel relief valves are to be provided at the exhaust ends or other approved positions of all main turbines, and the valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out device is provided, the sentinel relief valve at the L.P. exhaust may be omitted.

7.4.2 Sentinel relief valves are to be provided at the exhaust ends of all auxiliary turbines and the valve discharge outlets are to be visible and suitably guarded if necessary. Low vacuum or overpressure cut-out devices, as appropriate, are also to be provided for auxiliary turbines not installed with their own condensers.

7.5 Steam turbines for propulsion purposes

7.5.1 Where steam turbines for propulsion purposes are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by operators, they are to be provided with the alarm and safety arrangements required by 7.5.2 to 7.5.7 and Table 3.7.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

Table 3.7.1 Steam turbine machinery: Alarms and safeguards

Item	Alarm	Note
Lubricating oil pressure for turbines and gearing	1st stage Low	—
	2nd stage Low	Automatic shutdown *see* 7.5.2
Lubricating oil temperature for turbines and gearing	High	—
Lubricating oil sump level	Low	—
Lubricating oil filters differential pressure	High	—
Bearing temperatures or bearing oil outlet temperature of turbines and gearing	High	—
Astern turbine temperature	High	—
Gland steam pressure	High and low	—
Thrust bearing temperature	High	—
Sea water pressure or flow	Low	—
Turbine vibration	High	Shutdown or speed reduction of turbine(s)
Axial movement of turbine rotor	High	Shutdown or speed reduction of turbine(s)
Main condenser vacuum	Low	Shutdown or speed reduction of turbine(s)
Main condenser condensate level	High	Shutdown or speed reduction of turbine(s)
Overspeed	High	*See* 7.2

7.5.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 3.7.1 and 3.7.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

Table 3.7.2 Steam turbine machinery: Additional alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage Low	—
	2nd stage* Low	Automatic shutdown of turbine*, *see* 7.5.2
Condenser vacuum	Low	Automatic shutdown of turbine*
Axial displacement of rotor	High	
Overspeed	High	*See* 7.2

NOTE
There are no classification requirements for the items marked * in the case of engines being used for the emergency source of electrical power.
The arrangements are to comply with the requirements of the Naval Authority concerned.

7.5.3 Audible and visual alarms are to operate, and indication is to be given at the relevant control stations to stop or reduce the speed of the turbine(s) for the following fault conditions:
(a) Excessive turbine vibration.
(b) Excessive axial movement of turbine rotor.
(c) Low vacuum in main condenser.
(d) High condensate level in main condenser.

7.5.4 Reduction of speed may be effected by either manual or automatic control.

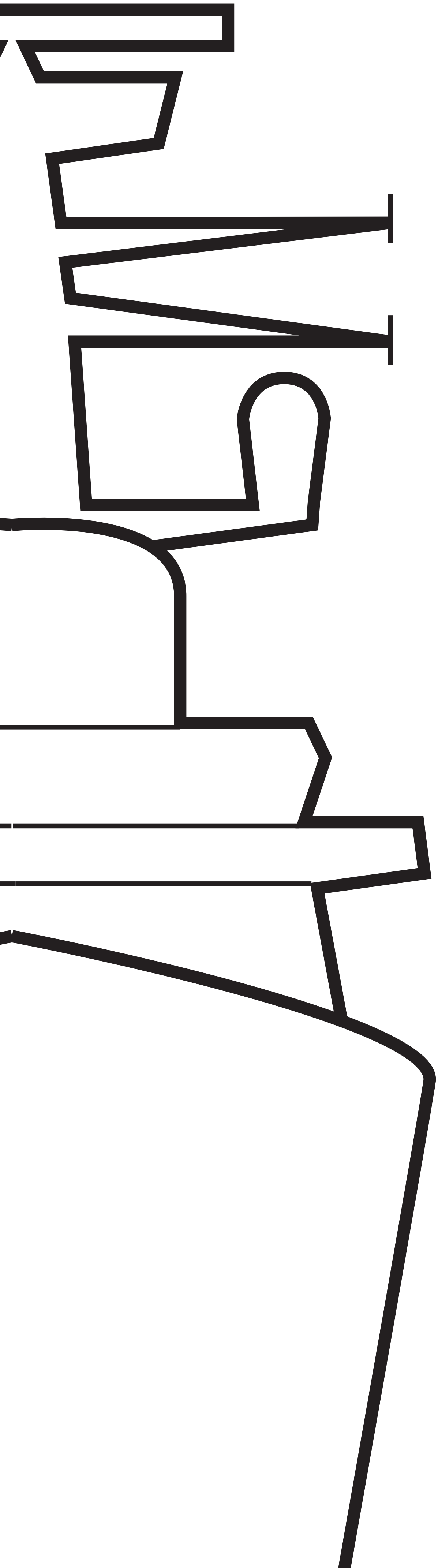
7.5.5 Means are to be provided to prevent the risk of thermal distortion of the turbines, by automatic steam spinning, when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to be provided at the relevant control stations when the shaft has been stopped for a predetermined time.

7.5.6 The following turbine services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the propulsion turbine(s):
(a) Lubricating oil supply temperature.
(b) Condenser condensate level.
(c) Gland steam pressure.

7.5.7 Prolonged running in a restricted speed range is to be prevented automatically, or alternatively, indication of restricted speed ranges is to be provided at each control station.

7.6 Steam turbines for auxiliary purposes

7.6.1 Where steam turbines for auxiliary purposes are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by operators, they are to be provided with the alarm and safety arrangements required by Table 3.7.2 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.



Rules and Regulations for the Classification of Naval Ships

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Transmission systems

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Chapter Contents

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Contents

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■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter defines the requirements for the design and service life of marine gears and is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 The scope of this Chapter includes gearing for main propulsion and auxiliary machinery, the support arrangements, the controls and systems necessary to maintain operation and functionality of the unit. The contents are in respect of mechanical integrity of the gears, control and monitoring systems and other support critical systems.

1.1.3 Marine gears utilised for propulsion or electrical power generation purposes are within the Mobility and Ship Type categories as defined in Pt 1, Ch 1,3.

1.1.4 The requirements of this Chapter are applicable to electric motor, gas turbine, steam turbines and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/ impeller(s) for main propulsion purposes where the transmitted powers exceed 220 kW.
(b) Auxiliary machinery that is essential for the safety of the ship or for the safety of persons on board where the transmitted powers exceed 110 kW.

1.1.5 Gear designs for applications other than those specified in 1.1.4 will be specially considered.

1.1.6 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.7 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.8 Gear type testing will be required as part of the approval process for first of type.

1.1.9 *See* Pt 1, Ch 2,10 for construction, installation and testing requirements.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Pt 1, Ch 2,4.3.

■ *Section 2* Principles

2.1 Design and operating principles

2.1.1 Marine gears are to be designed in accordance with user defined operating and performance criteria, taking account of ship type and service operating envelope.

2.1.2 Marine gears are to be capable of continuous operation between the maximum and minimum output power at specified operating conditions, *see* Pt 1, Ch 2,4.

2.1.3 Marine gears are to be designed and installed such that degradation or failure of any other independent system will not render the gears inoperable.

2.1.4 Marine gears necessary for propulsion or steering of the ship are to be designed and installed such that power transmission can be maintained in the event of single failure in an operational subsystem.

2.1.5 The gearing installation is to be capable of operating for the service profile throughout the specified life of the ship.

2.2 Lifecycle principles

2.2.1 Gears are to be operated and maintained such that the required performance, integrity and reliability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the classification provisions for engineering systems (*see* Pt 1, Ch 1,2.1.1), surveys are to be carried out in accordance with the Regulations.

2.3 Enhanced analysis principles

2.3.1 Where the design of gearing has used enhanced analysis methods as described in 2.3.2 to 2.3.5, the ship will be eligible for the optional machinery class notation **AG1** or **AG2** as applicable. These optional class notations may be applied where the Owner/operator requires detailed knowledge of the reliability of the gear elements and where noise excitation is required to be minimised for anticipated service conditions. Eligibility for the **AG1** class notation will be subject to analysis in accordance with ISO 6336 and the use of an acceptable validated analytical meshing model for determining the face load factor for contact stress $K_{H\beta}$ by direct calculations. The analytical mesh model is to include consideration of the following:

(a) Phase varying lines of contact at the mesh.
(b) Elastic deflection of the gears, supporting shafts and other supporting components.
(c) Geometric qualities of any helix and profile modifications.
(d) Manufacturing tolerances.

2.3.2 Where in addition to the requirements for **AG1** class notation, a validated three dimensional finite element program is used for determining the flexibility of the geometry of mating gears, the ship will be eligible for **AG2** class notation.

2.3.3 Gear elements are to be analysed using ISO 6336 with the following additions:

(a) The face load factor for contact stress (K_{Hmesh}) is to be calculated using an acceptable validated analytical meshing model and used in place of the equivalent factor ($K_{H\beta}$ x $K_{H\alpha}$) given in ISO 6336. The actual factor of safety against surface failure is effectively adjusted as follows:

$$S_H = S_{H_{ISO}} \frac{K_{H\beta}.K_{H\alpha}}{K_{Hmesh}} \quad \text{(to exceed 1,4)}$$

(b) The face load factor for bending stress (K_{Fmesh}) is to be calculated in accordance with ISO 6336 using the K_{Hmesh} value calculated from the validated analytical mesh model. The actual factor of safety against surface failure is effectively adjusted as follows:

$$S_F = S_{F_{ISO}} \frac{K_{F\beta}.K_{F\alpha}}{K_{Fmesh}} \quad \text{(to exceed 1,8)}$$

The factors of safety derived from the stress analysis procedure are only to be used for comparing the gears of similar design.

2.3.4 The ability of gearing to operate without scuffing at loads up to and including the maximum specified transient overload is to be demonstrated using at least two different methods. The assessment is to take full account of predicted transverse load distribution.

2.3.5 The design of the gearing is to be capable of accepting the following overload conditions as applicable and the over-speed without risk of damage:

(a) A non-transient ahead torque overload (duration of more than three seconds) of 125 per cent maximum full power torque in steam turbine and diesel installations, and of 150 per cent maximum full power torque in gas turbine installations. Torque levels up to these may occur during high power turns and rapid accelerations up to a total of five hours during a ship's life. Gears and shafts are to be capable of withstanding 200 per cent of full power statically as could occur if for instance the propeller becomes jammed.
(b) Over-speed of 15 per cent above the specified input speed.

■ *Section 3*
Acceptance criteria

3.1 General

3.1.1 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the gear manufacturer, shipbuilder and navy/operator to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR').

3.1.2 For gears, the applicable Rules, Standards for classification are:

(a) LR Rules for the Classification of Naval Ships.
(b) ISO 6336 Parts 1, 2, 3 and 5.
(c) ISO 1328 – *Parallel involute gears ISO System of Accuracy*.
(d) ISO 1940 – *Balancing*.
(e) Requirements of the Naval Authority, *see* 3.1.3.
(f) Other specific Owner requirements . These are to be identified before commencement of design review or construction.
(g) LR Type Approval System.
(h) LR Quality Scheme for Machinery.

3.1.3 Where LR is acting on behalf of the Naval Authority, any relevant requirements of the Naval Authority are to be identified and advised to LR.

■ *Section 4*
Design and construction

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of gears are:

(a) LR's Rules for Gearing, *see* Sections 5 to 9 and Pt 1, Ch 2,10.
(b) The gearing manufacturer's recommendations.

4.1.2 The overall performance of gears installed in ships is to be demonstrated to conform with the performance criteria specified. If necessary, tests may be carried out in conjunction with the ship's operational pattern.

■ *Section 5* Plans and particulars to be submitted

5.1 Plans

5.1.1 Particulars of the gearing are to be submitted with the plans, in triplicate, for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW.

5.2 Shafts and sub-systems

5.2.1 Plans showing details of shafts, bearings (position and type), couplings and any clutches are to be submitted.

5.2.2 Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures are to be submitted.

5.2.3 Schematic plans showing arrangements of the gearbox dehumidification arrangements are to be submitted.

5.2.4 Schematic plans showing arrangements of the control, safety and electrical systems are to be submitted.

5.3 Design data and calculations

5.3.1 A design statement for the gearing installation that details system capability and functionality under defined operating and emergency conditions.

5.3.2 A Failure Mode Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to include the following associated sub-systems:

- Clutches.
- Flexible couplings.
- Lubricating oil.
- Cooling arrangements.
- Dehumidification.
- Gearbox mounting.
- Control and monitoring.
- Electrical power supplies.

It is not necessary to consider failure modes relating to the gearbox components.

5.3.3 Details of calculations and tests to establish the service life of safety critical components, including couplings, gearing (where applicable), bearings and seals are to be submitted.

5.3.4 A technical file with bearing particulars, sizes, position of oil inlets, diametral clearances and lubricating oil arrangements are to be submitted.

5.3.5 Calculations demonstrating compliance with requirements for class notations **AG1** and **AG2** class notations are to be submitted where applicable.

5.3.6 Details of the turning gear and its operation limitations are to be provided.

■ *Section 6* Materials

6.1 General

6.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels provision is to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

6.1.2 Subject to 6.1.1, the specified minimum tensile strength is to be selected within the following limits:
(a) Pinion and pinion sleeves: 550 to 1050 N/mm^2.
(b) Gear wheels and rims: 400 to 850 N/mm^2.
A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 when the specified minimum tensile strength is 600 N/mm^2 or less. For higher strength steels, the range is not to exceed 150 N/mm^2.

6.1.3 Unless otherwise agreed by LR, the specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

6.1.4 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 HV for a depth of 0,25 mm.

6.2 Material specifications

6.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

6.2.2 Where the teeth of a pinion or gear wheel are to be surface hardened, i.e. carburized, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

Section 7
Design

7.1 General

7.1.1 Gears are to be designed to ISO 6336 Method B, or equivalent, and are to comply with the requirements of this Chapter.

7.1.2 It is the manufacturer's responsibility to provide, together with the requirements of 5.1.1, results of the calculations with all relevant input data.

7.2 Fatigue limits

7.2.1 Acceptable limiting fatigue bending stresses for various materials are given in Table 1.7.1. Where σ_B is the ultimate tensile strength, in N/mm^2, and HV is Vickers hardness number.

Table 1.7.1 Values of endurance limit for bending stress, $\sigma_{F\ lim}$

Heat treatment	$\sigma_{F\ lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (tuftrided)	330
Induction hardened	$0{,}35HV + 125$
Gas nitrided	390
Carburized A	450
Carburized B	410

NOTES
1. A is applicable for CR Ni Mo carburizing steels.
2. B is applicable for other carburizing steels.

7.2.2 Acceptable limiting fatigue surface stresses for various surface treatments are given in Table 1.7.2. Material mechanical properties are based on the gear wheel values.

Table 1.7.2 Values of endurance limit for Hertzian contact stress, $\sigma_{H\ lim}$

Heat treatment		$\sigma_{H\ lim}$ N/mm^2
Pinion	Wheel	
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface hardened	Through-hardened	$0{,}46\sigma_{B2} + 415$
Carburized, nitrided or induction-hardened	Soft bath nitrided (tuftrided)	1000
	Induction-hardened	$0{,}88HV_2 + 675$
Carburized, nitrided or induction-hardened	Nitrided	1300
Carburized or nitrided		
Carburized	Carburized	1500

7.3 Tooth form

7.3.1 The fundamental tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25 of gear normal modulus (mn).

7.4 Tooth loading factors

7.4.1 For values of application factor, K_A, *see* Table 1.7.3.

Table 1.7.3 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

7.4.2 Load sharing factor, K_g. The value for K_g is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise K_g is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

7.5 Factors of safety

7.5.1 The required factors of safety are shown in Table 1.7.4 where $S_{H\,min}$ relates to surface stress and $S_{F\,min}$ to bending stress.

Table 1.7.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

7.6 Gear wheels

7.6.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

7.7 Clutch actuation

7.7.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

7.8 Gearcases

7.8.1 Gearcases and their supports are to be designed to be sufficiently stiff such that movements of the external foundations and the thermal effects under all conditions of service do not disturb the tooth contact.

7.8.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. The attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

7.8.3 Access arrangements for examination and maintenance are to be provided for internal clutches, brakes, bearings and couplings where applicable.

7.8.4 Electrical equipment fitted within the gear case is to be suitable for installation in an oil-laden atmosphere and consideration is to be given to areas where oil sprays play directly onto electrotechnical equipment and/or cable fastenings. All electrical items are to be earthed to meet the requirements of Pt 10, Ch 1. Gearcases are to be earthed to the ship's structure.

7.8.5 For gearcase security arrangements, *see* Pt 7, Ch 3,8.10.2.

7.9 Alignment

7.9.1 Reduction gears with sleeve bearings are to be provided with means for checking the internal alignment of the various elements in the gearcases.

7.9.2 In the case of separately mounted reduction gearing for main propulsion means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

7.9.3 *See* Pt 5, Ch 4 for further requirements.

7.10 Turning gear

7.10.1 The gearbox is to be provided with a means of turning the gearing for inspection and maintenance purposes. The turning gear is to be designed to turn the shaft at a rate to allow visual inspection without risk to bearings when the oil supply is off. The turning gear arrangements are to provide means that enable ready operation by hand.

■ *Section 8* Sub-systems for gearing

8.1 General

8.1.1 The lubricating oil distribution system for gears and bearings is to comply with the gear manufacturer's requirements and recommendations.

8.1.2 Piping systems for gearing are to comply with the general design requirements in Pt 7, Ch 3. Specific requirements for lubricating/hydraulic oil systems and standby arrangements are also stated in Pt 7, Ch 3.

8.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakage onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems is to be kept to a minimum. Flexible pipes are to be of approved type.

8.2 Pumps

8.2.1 Where lubricating oil for gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with Pt 7, Ch 3.

8.3 Filters

8.3.1 Where lubricating oil for gearing is circulated under pressure, provision is to be made for efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gears or reducing the supply of filtered oil to the gearing.

8.4 Gearbox dehumidification

8.4.1 All gearboxes installed in **NS1** and **NS2** category ships are to be fitted with a dehumidifier to remove moist air from the gearcase during periods of shutdown.

8.4.2 The dry air produced by the dehumidifier is to have a relative humidity of no more than 30 per cent at 15°C.

Section 9
Control and monitoring

9.1 General

9.1.1 Control engineering systems are to be in accordance with Pt 9, Ch 1.

9.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Unattended machinery

9.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with alarms and safety arrangements required by 9.2.2 and Table 1.9.1. The sensors and circuits utilised for the second stage alarm and automatic shutdown in Table 1.9.1 are to be independent of those required for the first stage alarm.

Table 1.9.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of prime mover
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	
NOTE For transmitted powers of 1500 kW or less, only items marked * are required.		

9.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is start automatically if the discharge pressure from the working pump falls below a predetermined value.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see* Part 5), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see* Ch 1,7

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Pt 2, Ch 1, Ch 2 and Ch 3.

1.2 Power ratings

1.2.1 In this Chapter the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values used are those defined in Pt 1, Ch 2,4.3.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the ship are not endangered, either directly or by damaging the ship or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:

Shafting arrangement.
Thrust shaft.
Intermediate shafting.
Tube shaft, where applicable.
Screwshaft.
Shaft bearings fitted in sternbushes and shaft bossings in ‘A’ and ‘P’ brackets.
Screwshaft oil gland.
Screwshaft protection.
Sternbush, and arrangement in housing.
Couplings.
Coupling bolts.
Flexible coupling.
Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, ‘A’ bracket and propulsion device, as applicable.

2.1.3 A Failure Mode and Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to include the following associated sub-systems:

Clutches.
Flexible couplings.
Lubrication.
Cooling arrangements.
Bearing mountings.
Control and monitoring.
Electrical power supplies.
Thrust blocks.

It is not necessary to consider failure modes relating to the shafting components.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:

- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements to this Chapter, fatigue endurance calculations of all components according to Pt 1, Ch 2.

- Vibration analysis and alignment analysis as required by Part 5.
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component is to be stated. Where corrosion resistant material not included in Table 2.4.1 is used for un-protected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

■ *Section 3* Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of Volume 1, Part 2, *Rules for the Manufacture, Testing and Certification of Materials*.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting, not exposed to sea-water, in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 and for other forgings is not to exceed 1100 N/mm^2.

3.1.3 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured, from corrosion resistant ferrous or non-ferrous material, such as those indicated in Table 2.4.1.

3.1.4 In the selection of materials for shafts, keys, locking nuts etc., consideration is to be given to their compatibility with the proposed propeller material.

3.1.5 Where shafts are manufactured from composite material the process is to be approved.

3.2 Shaft bearing materials

3.2.1 Shaft bearings fitted in sternbushes and shaft bossings in 'A' and 'P' brackets are to be constructed from an approved material and effectively secured to prevent rotational and axial movement in the sterntube(s) and sternbush(es).

■ *Section 4* Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, *d*, of the intermediate shaft is to be not less than:

$$d = F\,k\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with 4.8 or shrink fit couplings
= 1,10 for shafts with keyways, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125*d*
= 1,10 for shafts with transverse or radial holes where the diameter of the hole does not exceed 0,3*d*
= 1,20 for shafts with longitudinal slots having a length of not more than 1,4*d* and a width of not more than 0,2*d* where *d*, is determined with k = 1,0

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings
= 100 for other diesel engine installations

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

4.2.2 Beyond a length of 0,2*d* from the end of a keyway, transverse hole or radial hole and 0,3*d* from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of k will be specially considered.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with 4.2 with a k value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a k value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea-water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the ship is in dry-dock, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tubeshafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screwshaft flange, is to be not less than:

$$d_p = 100\,k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \text{ mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with 4.4.3 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or $2{,}5d_p$ whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by 4.4.4 to the forward end of the stern tube seal is to be determined in accordance with 4.4.3 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in Table 2.4.1 is to be not less than:

$$d_{up} = 128A\sqrt[3]{\frac{P}{R}}$$

where A is taken from Table 2.4.1.

Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Nickel/aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of the unprotected screwshaft forward of the stern seal need not be greater than the diameter as required by 4.4.6.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o\sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is to be provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD}\,\frac{10^6}{\sigma_u}\,\frac{P}{R}} \quad \text{mm}$$

where

n = number of bolts in the coupling
D = pitch circle diameter of bolts, in mm
σ_u = specified minimum tensile strength of bolts, in N/mm^2.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

4.7.3 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348\sqrt{\left(\frac{120\;10^6\,F\,P\,(1 + C)}{R\,D} + Q\right)\frac{1}{n\,\sigma_y}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

F = 2,5 where the flange connection is not accessible from within the craft
= 2,0 where the flange connection is accessible from within the craft
C = ratio of vibratory/mean torque values at the rotational speed being considered
D = pitch circle diameter of bolt holes, in mm
Q = external load on in N (+ve tensile load tending to separate flange, –ve)
n = number of tap or clearance bolts
σ_y = bolt material yield stress in N/mm^2.

4.7.4 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 4.7.1, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 4.2.1.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.5 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of 4.11.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in Table 2.4.2, where

$$S_c = \frac{24{,}10^6\,P}{R d_p\, bhz} \quad \text{N/mm}^2$$

d_p = pitch circle diameter of coupling teeth, in mm
b = tooth face width, in mm
h = tooth height, in mm
z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE
For guidance purposes only $T_{max} = T_{mean}$ (1 + C)
where
C is to be taken from Table 2.4.3
S = 2,0 for assemblies accessible from within the vessel
= 2,5 for assemblies not accessible from within the vessel.

Table 2.4.3 '*C*' values for guidance purposes

Coupling location	*C*
High speed shafting – I.C engine driven	0,3
High speed shafting – Electric motor or turbine driven	0,1
Low speed shafting – main or PTO stage gearing	0,1

4.11.2 The effect of any axial load acting on the assembly is to be considered.

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_u \, d_1} \text{ mm}^2$$

where
d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1
d_1 = diameter of shaft at mid-length of the key, in mm
σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_y \, d_1} \text{ mm}^2$$

where
σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u \, d_1} \text{ mm}^2$$

where
d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1
d_1 = diameter of shaft at mid-length of the key, in mm
σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

Alternatively, consideration will be given to keys conforming to the design requirements of a recognized National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, *t*, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32} \text{ mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk on to the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see* Part 5.

4.16 Sternbushes and sterntube arrangements

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.

(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.

(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.

(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.

(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.

(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.

(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.

(e) Oil lubricated non metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.6 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space. *See also* 5.1.1.

4.16.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

4.16.9 Where in-water surveys are required, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Part 5.

4.18 Rope guards

4.18.1 Rope guards that provide effective mechanical protection for all bearing sealing arrangements are to be provided.

4.19 Shaft brake and locking arrangements

4.19.1 Where two or more propulsion shafts are installed, each propulsion system is to be provided with shaft brakes and locking arrangements complying with 4.19.2 and 4.19.3.

4.19.2 Shaft brakes for safely and speedily slowing down propulsion shafting systems are to be provided. Each shaft brake is to be capable of restraining the shaft system whilst the ship is being manoeuvred at slow speed and to hold the shaft while the shaft locking gear is being engaged. Shaft brakes are to be capable of functioning in a compartment that is flooded.

4.19.3 Means of safely securing the shafting systems in position are to be provided to permit the shaft to be locked in order to affect repairs whilst the ship is at sea and operating at a speed to maintain steering capability or not less than 7 knots, whichever is the greater.

■ *Section 5* Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.1.

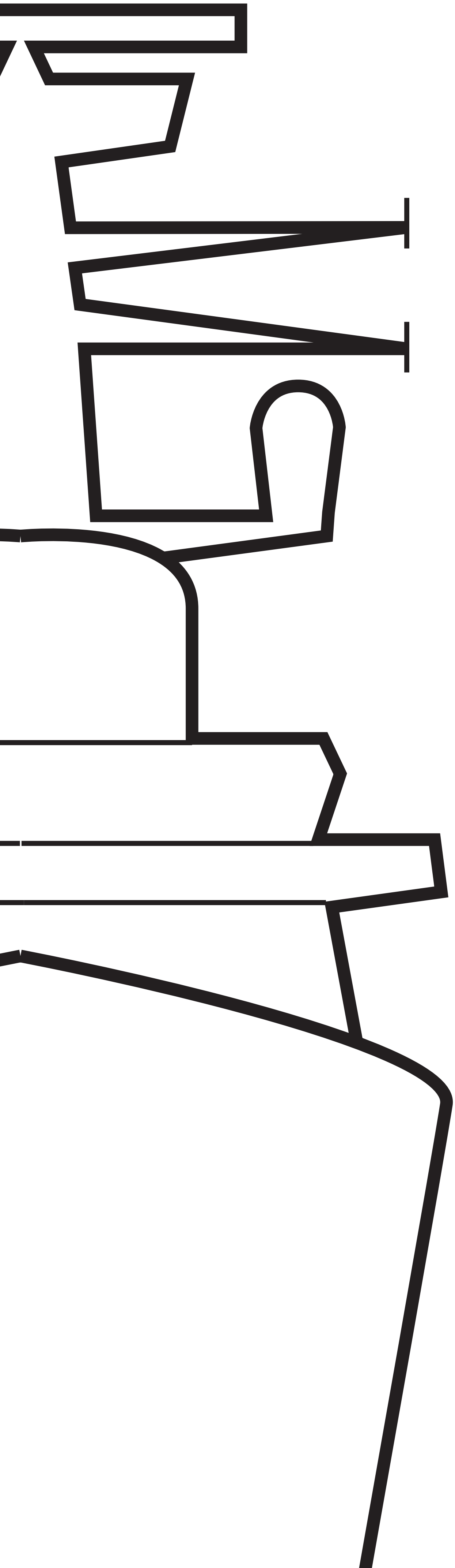
Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

5.1.2 Where shaft systems incorporate a separate thrust block(s) and lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.2.

Table 2.5.2 Alarms – Thrust block lubrication

Item	Alarm
Lubrication oil flow	Low
Lubrication oil temperature	High
Bearing temperature	High



Rules and Regulations for the Classification of Naval Ships

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Propulsion Devices

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Lloyd's Register

Chapter Contents

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■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter defines the requirements for the design and service life of marine propellers for naval ships and is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 The scope of this Chapter includes propellers for main propulsion, the support arrangements, the controls and systems necessary to maintain operation and functionality of the propeller. The contents are in respect of mechanical integrity of the propeller, control and monitoring systems and other support critical systems.

1.1.3 Marine propellers utilised for propulsion purposes are within the Mobility category as defined in Pt 1, Ch 1,3.

1.1.4 With the exception of the requirements of Section 8, this Chapter is applicable to fully immersed propellers that are non-ducted. The propellers may be non-cavitating, partially cavitating or supercavitating.

1.1.5 Propeller designs for applications other than those specified in 1.1.4 will be specially considered.

1.1.6 *See* Pt 1, Ch 2,12 for construction, installation and testing requirements.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Propeller skew angle definition

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade geometric tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections (*see* Fig. 1.1.1).

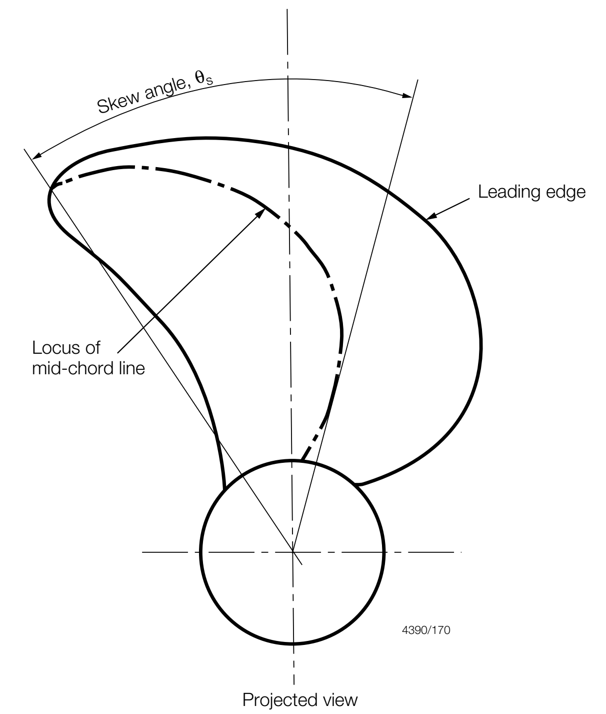


Fig. 1.1.1 Definition of skew angle

■ *Section 2* Principles

2.1 Design and operating principles

2.1.1 Marine propellers are to be designed in accordance with user defined operating and performance criteria, taking account of ship type and service operating envelope. In multi-screw ships, consideration is to be given to operating modes where one or more propeller is out of service.

2.1.2 Marine propellers are to be capable of continuous operation between the maximum and minimum output power at specified operating conditions, *see* Pt 1, Ch 2,4 and within the operational service profile required by 5.2.2 in this Chapter.

2.1.3 Marine propellers are to be designed and installed such that degradation or failure of any other propulsion system will not render the propeller inoperable.

2.1.4 Marine propellers are to be designed and installed such that power transmission can be maintained in the event of a single failure in an operational subsystem.

2.1.5 The propeller is to be capable of operating within defined vibration, cyclic or other loads during its service life.

2.1.6 Controllable pitch propellers shall be designed so that all blades are interchangeable and will fit into any blade seat on the hub.

2.2 Lifecycle principles

2.2.1 Propellers are to be operated and maintained such that the required performance, integrity and reliability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the classification provisions for engineering systems (*see* Pt 1, Ch 1,2.1.1), surveys are to be carried out in accordance with the Regulations.

2.3 Enhanced assessment of manufacturing tolerance principles

2.3.1 Where the design of a propeller has used enhanced assessment methods for manufacturing tolerances as described in 8.4 and 8.5, the ship will be eligible for the optional machinery class notation **AP1** or **AP2** as applicable. These optional class notations may be applied where the Owner/Operator requires detailed knowledge of a propeller's manufacturing tolerances and where noise or the effects of cavitation are required to be minimized for anticipated service conditions.

■ *Section 3* Acceptance criteria

3.1 General

3.1.1 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the propeller manufacturer, shipbuilder and Navy/Operator to the satisfaction of Lloyd’s Register (hereinafter referred to as ‘LR’).

3.1.2 For propellers, the applicable Rules and Standards for classification are:

(a) LR Rules for the Classification of Naval Ships.
(b) ISO 484/1 Shipbuilding – Ship Screw Propellers – Manufacturing Tolerances, Part 1: *Propellers of Diameter greater than 2,5 m.*
(c) ISO 484/2 Shipbuilding – Ship Screw Propellers – Manufacturing Tolerances, Part 2: *Propellers of Diameter between 0,8 and 2,5 m inclusive.*
(d) Requirements of the Naval Authority, *see* 3.1.3.
(e) Other specific Owner requirements. These are to be identified before commencement of design review or construction.
(f) LR Quality Scheme for Machinery.

Where it is proposed to use manufacturing tolerances other than those stated in the ISO standards, these are to be agreed between the manufacturer and the Owner and advised to LR.

3.1.3 Where LR is acting on behalf of the Naval Authority, any relevant requirements of the Naval Authority are to be identified and advised to LR.

■ *Section 4* Routes to conformance

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of propellers are:

(a) LR's Rules for Propellers; *see* Sections 5 to 10 of this Chapter and Pt 1, Ch 2,12.
(b) The propeller manufacturer's recommendations.

4.1.2 The overall performance of installed propellers is to be demonstrated for conformance with the performance criteria specified. If necessary these tests may be carried out in conjunction with the ship's operational pattern.

■ *Section 5* Plans and particulars

5.1 Particulars to be submitted

5.1.1 Particulars of the propellers are to be submitted with the plans, in triplicate, as described in 5.2 to 5.3.

5.2 Plans

5.2.1 Plans of the propeller, together with the following particulars are to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, T, in mm.
(b) Maximum shaft power (*see* Pt 1, Ch 2), P, in kW.
(c) Estimated ship speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Blade section nose-tail pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.

(g) Blade section nose-tail pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Blade section nose-tail pitch at 60 per cent radius, $P_{0,6}$, in metres.
(j) Blade section nose-tail pitch at 70 per cent radius, $P_{0,7}$, in metres.
(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(m) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(o) Number of blades, N.
(p) Expanded area ratio, B.
(q) Material: type and specified minimum tensile strength.
(r) Skew angle, θ_s, in degrees (*see* Fig. 1.1.1).
(s) Connection of propeller to shaft, details of fit, push up, securing.
(t) Keyed connections details.
(u) Details of control/hydraulic system and pressures for controllable pitch propeller actuating mechanisms.
(v) Inertia of propeller assembly, specified either as GD^2 or Wk^2, in kgm^2.
(w) Total mass of propeller assembly, in kg.

5.2.2 The design operational service profile for the life of the ship is to be submitted. For fixed pitch propellers, this data is to be supplied in terms of a table or histogram showing the proportion of time anticipated to be spent within a particular speed range from zero to full speed. In the case of controllable pitch propellers, the combinator diagram is to be submitted and this is to show the propeller rotational speed, blade pitch angle at 0,7R and power absorbed against the control lever position. Additionally, for these types of propeller the proportion of time planned to be spent at a particular rotational speed, between the minimum and maximum speed ranges, is to be specified in terms of a histogram or table.

5.2.3 For propellers having a skew angle equal or greater than 50°, in addition to the particulars detailed in 5.2.1 and 5.2.2, details are to be submitted of:
(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the estimated ahead mean ship effective wake condition and when absorbing full power:
  (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
  (ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

5.2.4 Where propellers as defined in 1.1.4, are intended for more than one operating regime, such as towing duties, then a detailed blade stress calculation for each operating condition indicating the rotational and ship speed, is to be submitted for consideration.

5.2.5 Where it is proposed to fit a fixed pitch propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screwshaft, propeller nut and where applicable, the sleeve, are to be submitted.

5.2.6 Where it is proposed to use a controllable pitch propeller, calculations are to be submitted which demonstrate the design integrity of the pitch control mechanism contained within the hub. Details of the associated piping arrangements are to be submitted. The submission is to include justification for the selection of the associated sealing arrangements within the hub, *see* 7.5.3.

5.3 Calculations and information

5.3.1 In cases where the vessel has been the subject of model wake field tests, a copy of the results is to be submitted together with details of the model dimensions, scale and test conditions.

5.3.2 The following information is to be submitted as applicable.
(a) For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
(b) Details of control engineering aspects in accordance with Pt 9, Ch 1.
(c) Calculations, or relevant documentation indicating the suitability of all components for short-term high power operation. Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
(d) For cases where the propeller material is not specified in Table 1.6.1, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in artificial sea water (3 per cent NaCl) to enable a value for U to be assigned.

5.3.3 Methods for demonstrating compliance with requirements for class notations **AP1** and **AP2** are to be submitted where applicable.

■ *Section 6* Materials

6.1 Castings for propellers

6.1.1 Castings for propellers and propeller blades are to comply with the requirements of Volume 1, Part 2, *Rules for the Manufacture, Testing and Certification of Materials*. The chemical composition and mechanical properties of steel castings are given in Vol 1, Pt 2, Ch 4,5 and those of the copper alloys are given in Vol 1, Pt 2, Ch 9,1.

6.1.2 The specified minimum tensile strength of the castings is to be not less than stated in Table 1.6.1.
The values of U in Table 1.6.1 relate to castings of less than 25 tonnes in weight.

Table 1.6.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	35
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	35
Grade Cu 3 Ni-Aluminium bronze	590	7,6	53
Grade Cu 4 Mn-Aluminium bronze	630	7,5	45

Section 7 Propeller design

7.1 Minimum blade thickness

7.1.1 For propellers having a skew angle of less than 25° as defined in 1.3.1, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase in each case due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{0{,}5KVZ}{(0{,}11ENLU_a - KWZ)} + 2450\sqrt{\frac{PCM}{RF(0{,}11ENLU_a - KWZ)}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$ as appropriate

$K = \dfrac{GBR^2\,D^3}{673}$

G = density of the blade material in g/cm^3, *see* Table 1.6.1

U_a = design allowable stress in N/mm^2 derived from the allowable stress U, by the relationship $U_a = \phi_u U$

Where ϕ_u is a factor in the range unity to 1,5 and is governed by the design operational profile of the ship. If 50 per cent or more of the design life of the propeller is to be spent operating at powers below 0,4*P*, then the value of ϕ_u is governed by the anticipated design life number of revolutions (n) that the propeller will experience within the power range 0,75*P* to *P* of the propulsion machinery. As such, for bronze and stainless steel alloys:

If $n \leq 10^7$ revolutions $\phi_u = 1{,}5$

If $10^7 < n \leq 10^9$ revolutions $\phi_u = 3{,}25 - \dfrac{\log_{10}(n)}{4}$

If $n > 10^9$ revolutions $\phi_u = 1{,}0$

For other operational profiles the value of ϕ_u must be specially justified.

When high damping alloys are used, then ϕ_u is to be taken as unity for all values of n.

U = allowable stress in N/mm^2, *see* 7.1.2, 7.1.3 and Table 1.6.1

$E = \dfrac{\text{actual section modulus}}{0{,}11T^2\,L}$

The coefficient *Z* is given by Table 1.7.1.

Table 1.7.1 Values of *Z*

Per cent radius	25	35	60
Fixed pitch propellers	0,5	–	0,36
Controllable pitch propellers	–	0,53	0,46

For solid propellers at 25 per cent radius:

C = 1,04

$F = \dfrac{P_{0,25}}{D} + 0{,}70$

$M = \lambda_T\left(1 + \dfrac{3{,}75D}{P_{0,7}}\right) + 2{,}03\lambda_Q\left(\dfrac{P_{0,25}}{D}\right)$

For controllable pitch propellers at 35 per cent radius:

C = 1,72

$F = \dfrac{P_{0,35}}{D} + 1{,}34$

$M = \lambda_T\left(1 + \dfrac{3{,}75D}{P_{0,7}}\right) + 1{,}45\lambda_Q\left(\dfrac{P_{0,35}}{D}\right)$

For all propellers at 60 per cent radius:

C = 4,17

$F = \dfrac{P_{0,6}}{D} + 3{,}75$

$M = \lambda_T\left(1 + \dfrac{3{,}75D}{P_{0,7}}\right) + 0{,}84\lambda_Q\left(\dfrac{P_{0,6}}{D}\right)$

The value of *W* is to be taken as 0,16 for fixed pitch propellers and 0,12 for controllable pitch propellers.

The parameter *V* is the centrifugal bending moment lever acting at each of the Rule stress sections, in mm. For linear distributions of rake along the blade, the value of *V* can be determined from the following relationships:

$V_{0,25} = \dfrac{A}{3{,}85F}$

$V_{0,35} = \dfrac{A}{3{,}23F}$

$V_{0,60} = \dfrac{A}{1{,}84F}$

When non-linear distributions of blade rake are used, then the value of *V* must be calculated individually for each stress section and the supporting calculation submitted along with the other information required in 5.2.1.

For optimum free-running propellers, the values of λ_T and λ_Q can be taken from Table 1.7.2.

Table 1.7.2 Values of λ_T and λ_Q

Per cent radius		25	35	60
Fixed pitch propellers	λ_T	0,45	–	0,14
	λ_Q	0,62	–	0,13
Controllable pitch propellers	λ_T	–	0,38	0,15
	λ_Q	–	0,48	0,14

For non-optimum and tip reduced circulation propellers, the values of the parameters λ_T and λ_Q are to be derived from the following expressions for 25, 35 and 60 per cent Rule radii, as applicable:

$$\lambda_T = \left[\frac{\int_x^{1,0} F'_T \bullet \xi \, d\xi}{\int_x^{1,0} F'_T \, d\xi} - x \right] \bullet \frac{\int_x^{1,0} F'_T \, d\xi}{\int_{x_h}^{1,0} F'_T \, d\xi}$$

and

$$\lambda_Q = \frac{\dfrac{\int_x^{1,0} F'_Q \bullet \xi \, d\xi}{\int_x^{1,0} F'_Q \, d\xi} - x}{\dfrac{\int_x^{1,0} F'_Q \bullet \xi \, d\xi}{\int_x^{1,0} F'_Q \, d\xi}} \bullet \frac{\int_x^{1,0} F'_Q \, d\xi}{\int_{x_h}^{1,0} F'_Q \, d\xi}$$

where

ξ = a non-dimensional radius between the integration limits

x = the Rule non-dimensional radius, 0,25, 0,35 or 0,6 whichever is appropriate

x_h = either the boss or hub non-dimensional radius depending on whether a solid or controllable pitch propeller is being considered

F'_T = elemental thrust forces acting on the blade sections

F'_Q = elemental torque forces acting on the blade sections.

7.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

7.1.3 The value U when used for determining U_a may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships and craft.

7.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid-chord thickness. $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0,54 T_{0,6} \sqrt{(1 + 0,1\theta_s)} \text{ mm}$$

The mid chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0,75 T_{root} \sqrt[4]{(1 + 0,1\theta_s)} \text{ mm}$$

where

θ_s = proposed skew angle as defined in 1.3.1

$T_{0,6}$ = thickness at 60 per cent radius, calculated by 7.1.1

T_{root} = thickness at 25 per cent radius or 35 per cent radius, calculated by 7.1.1

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

7.1.5 Results of detailed calculations where carried out, are to be submitted.

7.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less then required by 7.1.1 but maintaining the required value of U_a, a detailed stress analysis for the blades is to be submitted for consideration.

7.2 Fluid channels in propellers and blades

7.2.1 Where it is required to emit air or other fluids from the blades of propellers, then the channels conducting the fluid are to be arranged such that they pass through low stressed regions of the blades.

7.2.2 Full details of any fluid channels in the propeller and its blades, including the method of manufacture and the details of any closing plates together with any required welding processes and procedures, are to be submitted for consideration together with supporting stress calculations. Consideration is to be extended to the method of transferring the emission fluid though the propulsion system to the propeller and the safety devices provided to accommodate the effects of a failure of the fluid transfer system.

7.2.3 In cases where it is considered necessary to introduce holes, passing from the suction to pressure surfaces of the blades, in order to control cavitation in the blade root sections the details of these arrangements, together with supporting calculations, are to be submitted for consideration. Such holes are to be designed with blending radii from the hole to the blade surface but need not be of constant profile. Furthermore, if any throttling or other arrangements are required to be fitted within the holes, then full design calculations and fitting details are to be submitted.

7.3 Interference fit of keyless propellers

7.3.1 The symbols used in 7.3.2 are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$k_3 = \dfrac{d_3}{d_1}$

$l = \dfrac{d_i}{d_1}$

$p_1 = \dfrac{2M}{A_1\,\theta_1\,V_1}\left(-1+\sqrt{1+V_1\left(\dfrac{F_1^2}{M^2}+1\right)}\right)$

A_1 = contact area fitting at screwshaft, in mm^2

$B_3 = \dfrac{1}{E_3}\left(\dfrac{k_3^2+1}{k_3^2-1}+\nu_3\right)+\dfrac{1}{E_1}\left(\dfrac{1+l^2}{1-l^2}-\nu_1\right)$

C = 0 for turbine installations or electric propulsion

= $\dfrac{\textit{vibratory torque at the maximum service speed}}{\textit{mean torque at the maximum service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$F_1 = \dfrac{2000Q}{d_1}(1+C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Pt 1, Ch 2, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

$V_1 = 0{,}51\left(\dfrac{\mu_1}{\theta_1}\right)^2 - 1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \le \dfrac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material.

7.3.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3-\alpha_1)(35-T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_o of the propeller material is to be not less than:

$$\sigma_o = \frac{1{,}4}{B_3}\left(\frac{\theta_1\,\delta_p}{d_1}+T_1(\alpha_3-\alpha_1)\right)\frac{\sqrt{3k_3^4+1}}{k_3^2-1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002+\frac{\theta_1}{20}\right)\left(p_1+\frac{18}{B_3}(\alpha_3-\alpha_1)\right) \text{ N}$$

7.4 Keyed propellers pushed up by a hydraulic nut

7.4.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of fretting a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

7.5 Propeller boss and hubs

7.5.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

7.5.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

7.5.3 The mechanisms contained within the hubs of controllable pitch propellers and their associated piping arrangements are to be designed to be capable of operating within defined vibration, cyclic or other loads during their service life. As such, a factor of safety of 1,5 is to be demonstrated against all modes of failure for components in the pitch control system, at full power operating conditions. Similarly, the sealing systems within the hub mechanism are to be selected to provide integrity of operation within defined survey or inspection intervals.

■ *Section 8* Propeller tolerances

8.1 General

8.1.1 This section applies to conventional fixed and controllable pitch propellers, ducted propellers, super-cavitating and surface piercing propellers.

8.1.2 All propellers are to have manufacturing tolerances specified on the design drawings.

8.1.3 Adequate records defining the manufactured dimensions of the propeller are to be maintained in order that subsequent compliance with the requirements of this Section can be demonstrated.

8.1.4 The fitting of the propeller to the shaft interface is dealt with separately in 7.3 and 7.4.

8.2 Minimum requirements

8.2.1 As a minimum requirement for all naval surface ship types, with the exception of work boats and very low performance craft having speeds below 10 knots, the Class 1 requirements of the ISO 484/1 or 484/2 specifications are to be applied.

8.2.2 For work boats and very low performance craft having speeds below 10 knots, the Class 2 requirements of the ISO 484/1 or 484/2 specifications may be applied.

8.3 Balancing

8.3.1 After the production processes and assembly, where appropriate, have been completed the propeller must be statically balanced by an approved method, details of which are to be submitted.

8.3.2 For fixed pitch propellers the propeller and cone must each be statically balanced according to the requirements of Table 1.8.1.

Table 1.8.1 Balancing requirements

Propeller rotational speed	Balance criterion
Up to 200 rpm	± 0,225 kgf.m/tonne
200 to 400 rpm	$\pm \dfrac{9000}{R^2}$ kgf.m/tonne

8.3.3 For controllable pitch propellers the blades, hubs and fairing cones are to be balanced separately. For propellers having rotational speeds between 200 and 400 rpm the maximum allowable total imbalance is $\pm 15000/R^2$ kgf.m/tonne. For propellers having rotational speeds less than 200 rpm, the maximum allowable total imbalance is ±0,375 kgf.m/tonne.

8.3.4 For propeller rotational speeds greater than 400 rpm then special consideration will be given to the balancing method, whether it should incorporate dynamic effect and the balance limits. Dynamic balancing tests may be required for high rotational speed propellers where significant out-of-balance couples can be exerted on the shafting. Such tests are to be agreed between the manufacturer and Owner and advised to LR.

8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft

8.4.1 For ships and craft having displacements below 500 tonnes and speeds in excess of 25 knots that require the enhanced assessment of propeller manufacturing tolerances notation **AP1**, the Class S requirements of the ISO 484/1 or 484/2 specifications are to be applied in addition to 8.4.2 to 8.4.5.

8.4.2 In addition to the leading edge templates required by 8.4.1, radial root fillet templates are to be provided at 0 per cent, 5 per cent, 10 per cent and 20 per cent of the chordal length from the leading edge in the blade roots.

8.4.3 A mid-fillet, in the radial sense, blade leading edge chordal template is to be provided. This template is to define the root fillet geometry from the leading edge to the 20 per cent chordal location from the leading edge and is to be based on the designed back and face surfaces of the propeller blade. The manufactured blade profile is to be demonstrated to lie within a tolerance band of ± 0,5 mm.

8.4.4 The diameter of the propeller boss is to be checked at four equi-distant axial stations along the boss length. These stations are to include the forward and aft faces of the propeller boss. The diameters measured at the four axial stations of the boss must be shown to lie within ±1 mm from the design value.

8.4.5 If the design incorporates through blade penetrations, two plug templates, one in the radial and the other in the chordal direction, must be provided for each type of penetration so as to define the design penetration to blade surface geometry. The manufactured intersection geometry must be shown to lie within ±0,5 mm of the design intent. Additionally, the tolerance for the surface finish of the intersection geometry shall be 3 μm Ra.

8.5 Enhanced assessment of propeller manufacturing tolerances – Noise reduced propellers

8.5.1 For ships having noise reduced propellers and requiring the enhanced assessment of propeller manufacturing tolerances notation **AP2**, the Class S requirements of the ISO 484/1 or 484/2 specifications are to be applied in addition to 8.5.2 to 8.5.5.

8.5.2 The requirements of Table 1.8.2 are to be satisfactorily achieved.

8.5.3 In order to adequately control the blade shape the local pitch errors of any two consecutive measurements are not to differ by more than half the local pitch tolerance envelope.

8.5.4 To control the shape of the pressure face of the blade, the algebraic sum of the local pitch errors of any two consecutive measurements is not to exceed 75 per cent of the local pitch tolerance envelope.

8.5.5 To limit chordwise deviations of the suction surface of the blade, local thickness errors are not to differ by more than half the thickness tolerance envelope between any two consecutive measurements.

Table 1.8.2 Manufacturing tolerances

Dimension	Tolerance
Angular spacing between blade reference lines at all radii	± 0,25 degrees
Difference between blade reference line and section leading or trailing edge	± 0,5% of the chord length with a minimum value of ± 1 mm
Fit of template inside the hook of the leading edge	+ 0 mm – 0,2 mm
Fit of face templates and outside the hook of leading edge templates	+ 0 mm – 0,5 mm
Blade axial position	± 0,25% of propeller diameter with a minimum value of ± 5 mm
Boss diameters	± 0,5 mm
Boss length	± 0,5 mm
Surface finish	<1,6μm

■ *Section 9*
Piping systems

9.1 General

9.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in Pt 7, Ch 3.

9.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Pt 7, Ch 3.

9.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 10*
Control and monitoring

10.1 General

10.1.1 Control and monitoring is to comply with the requirements of Pt 9, Ch 1.

10.2 Automatic and remote controls

10.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 10.2.2, 10.2.3 and Table 1.10.1.

Table 1.10.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic acturator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See* Pt 9, Ch 1

10.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

10.2.3 Controllable pitch propellers are to be provided with an indication of shaft speed, an indication of direction, an indication representative of the magnitude of thrust and an indication of propeller pitch as a measure of the propeller blade or actuator movement at each station from which it is possible to control shaft speed or propeller pitch.

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 This Chapter gives requirements for fixed or steerable water jet propulsion systems where the rated power exceeds 500 kW, and which are integral with the ship's hull structure and form the main means of propulsion. The arrangements of water jet units for other purposes will be considered in relation to their intended duty.

1.1.3 A water jet propulsion unit is defined as a machine which takes in water, by means of a suitable inlet and ducting system, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system.

1.2 Redundancy

1.2.1 In general a minimum of two water jet units are to be provided where these form the sole means of propulsion.

1.2.2 The failure of one water jet unit or its control system is not to render any other water jet unit inoperative.

1.2.3 Where a single water jet installation is proposed, it will be subject to special consideration, taking into account the proposed restricted area notation. A formal risk assessment will be required in these cases.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Longitudinal section of the complete water jet unit.

2.2.2 Detailed dimension plans indicating scantlings and materials of construction of the following:

(a) Arrangement of the system, including intended method of attachment to the hull and building in, geometry of tunnel, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including impeller, and also stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This includes steerable exit water jet nozzles where fitted.
(d) Components of retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.
(f) Shaft sealing arrangements.
(g) Details of any shafting support or guide vanes used in the water jet system.

2.2.3 Schematic plans of the lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.3 Calculations and information

2.3.1 Details of the power/speed range of operation indicating the maximum continuous torque rating together with flow rate and thrust.

2.3.2 Strength calculations, using the maximum continuous torque rating and the most 'onerous' operating condition, including short term high power operation, as a design case including the effects of mean and fluctuating loads, residual stresses, and stress raisers, for:

(a) Impeller and, if fitted, the stator and any bolting arrangements.
(b) Shaft supports and guide vanes if fitted.
In the absence of precise information, the fluctuating stress may be assumed to be 15 per cent of the maximum stress. As an alternative to fatigue strength calculation results of an approved measurement programme may be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum continuous rating condition.

(c) Detailed weld specification where an impeller has welded blades. Welds are to be full penetration type or of equivalent strength.
(d) Steering components, including lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanism, which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with appropriate full scale or model test data or satisfactory service experience to validate the design method.

2.3.3 Details of the Designer's loadings and positions of application in the hull are to be submitted, and should include maximum applied thrust, moments and tunnel pressures. The tunnel strength and supporting structure are to be examined by direct calculation procedures and submitted for consideration.

2.3.4 Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.

2.3.5 Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

2.3.6 Torsional vibration calculations of the complete dynamic system in accordance with Pt 5, Ch 1 together with a torsional schematic of the water jet unit.

2.3.7 Shaft whirling calculations where required by Pt 5, Ch 3.

2.3.8 Details of control engineering aspects are to be in accordance with Pt 9, Ch 1.

■ *Section 3*
Materials

3.1 General

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with, Volume 1, Part 2 *Rules for the Manufacture, Testing and Certification of Materials*.

3.1.2 Machinery components are to be of steel or other approved non-ferrous metals suitable for the intended environment.

■ *Section 4*
Design and construction

4.1 Shaftline

4.1.1 The diameter of the shafting is to comply with Pt 3, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

4.1.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected. Full details of the means of protection are to be submitted.

4.1.3 Where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force are to be forwarded for consideration. A factor of safety against slippage of 2,0, based upon mean plus vibratory torque, is to be achieved for couplings located inboard, and likewise 2,5 for couplings which are located outboard.

4.1.4 For the interference fit of keyless impellers the requirements of Chapter 1 are to be applied.

4.2 Shaft support system and guide vanes

4.2.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller, or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

4.2.2 Fatigue strength calculations of supports or guide vanes are to be submitted and are to include the effects of mean and fluctuating loads, residual stresses, and stress raisers. In general, the fillet radius should not be less than the maximum thickness at that location. Smaller radii may be considered for which the results of an approved measurement programme are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the designed operating conditions.

4.2.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or boroscope inspection of these components.

4.3 Impeller

4.3.1 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

4.3.2 Where an impeller has bolted on blades, consideration is also to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

4.3.3 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes must be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

4.3.4 A calculation of the blade natural frequency for the impeller blades is to be undertaken. As such the natural frequency should be shown to lie outside any expected excitation frequencies within a speed range of 30 per cent below to 10 per cent above the maximum impeller speed. Deviations from these limits will be considered.

4.3.5 A facility for the in service inspection of the impeller and stator (if fitted) blades is to be provided which will allow for either a direct visual or boroscope inspection of the complete blade surfaces.

4.4 Stator

4.4.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydro-dynamic and mechanical loads (including any loads transmitted via shaft bearings) developed by the unit and reacted through the blades when the impeller is absorbing full power and the vessel is either free running or undergoing a crash stop manoeuvre, whichever imposes the greater loading on the blades.

4.4.2 In general, the fillet radius should not be less than the maximum thickness at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

4.4.3 If the stator ring is a composite assembly then consideration is also to be given to the distribution of stress in the various adjacent members.

4.4.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to be carried out and it is to be demonstrated that this does not coincide with the natural frequency of the stator blades over a speed range of 30 per cent below to 10 per cent above maximum impeller speed. Similarly this condition is to be demonstrated for the manoeuvring speeds.

4.4.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

4.4.6 Where the stator blading assembly forms part of the nozzle, the requirements of 4.6 must be considered in association with those for the stator assembly.

4.5 Tunnel and securing arrangements

4.5.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure.

4.5.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

4.5.3 Consideration should be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard must strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

4.5.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separating of the flow into the rotating machinery.

4.5.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage, and to the axial location of rotating parts.

4.6 Nozzle and reversing bucket

4.6.1 Nozzles can be either of a fixed or steerable form. The design of the nozzle must fully take into account the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments and bucket loads which may be reacted through the body of the nozzle. In this analysis the changes to the pressure distribution caused by transient manoeuvres are to be considered.

4.6.2 Consideration is to be given to all transient loads the bucket is likely to experience from manoeuvring and the sea conditions.

4.6.3 The bucket is to be given reasonable mechanical protection from other impact damage such as collision with harbour walls, other vessels, buoys, etc.

4.7 Steering system

4.7.1 In general the steering systems are to comply with the requirements of Pt 6, Ch 1.

4.7.2 In addition to the requirements of Pt 6, Ch 1, the steering mechanism is to be capable of turning the nozzle unit at not less than 1,5 rev/min.

Section 5
Piping systems

5.1 General

5.1.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 7, Ch 1.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Pt 7, Ch 3. Requirements for steering hydraulic systems are given in Pt 6, Ch 1.

5.2 Hydraulic power systems

5.2.1 The piping systems for a water jet unit are to comply with the general requirements of Pt 7, Ch 1.

5.2.2 The hydraulic power operating systems for each water jet unit are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system; and

(b) a fixed storage tank having sufficient capacity to recharge at least one water jet power actuating system including the reservoir.

Section 6
Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 9, Ch 1.

6.1.2 Steering control is to be provided for the water jet from machinery control stations.

6.1.3 For water jets used as the only means of propulsion, a standby or alternative power source of actuating medium for controlling the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

6.1.4 Means are to be provided at each station to stop each water jet.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2 to 6.2.4 and Table 2.6.1.

6.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust.

Table 2.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Hydraulic system flow	Low	–
Lubricating oil pressure	Low	–
Control system	Fault	–
Control system power supply	Failure	–

6.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

6.2.4 The alarms described in Table 2.6.1 are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 9, Ch 1.

Section 7
Electrical systems

7.1 Distribution arrangements

7.1.1 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, convertors, protective devices or control circuits.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of ship

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in Pt 1, Ch 2,4.3.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 **Fixed/Azimuth propulsion thrusters**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.
(b) Detailed and dimensional plans of the individual torque transmitting components.
(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.2.2 **Tunnel thrusters.** Structural assembly plan including connections to tunnel.

2.3 Calculations and specifications

2.3.1 **Fixed/Azimuth propulsion thrusters**

(a) Thruster prime mover type and operational power/speed envelope.
(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).
(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.
(d) Bearing specifications.
(e) Details of control engineering aspects in accordance with Pt 9, Ch 1.
(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See* Pt 1, Ch 2.
(g) Where carried out in accordance with Pt 1, Ch 2, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.3.2 **Tunnel thrusters.** Specification for materials of gears, shafts, couplings and propeller, stock and struts.

■ *Section 3* **Materials**

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with Volume 1, Part 2, *Rules for the Manufacture, Testing and Certification of Materials*.

■ *Section 4* **Design and construction**

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with Vol 1, Pt 3, Ch 3.

4.1.3 In addition to the requirements of this Section reference is to be made to:

(a) Main transmission gearing (Pt 3, Ch 1).
(b) Main transmission shafting (Pt 3, Ch 2).
(c) Propeller (Chapter 1).
(d) Torsional vibration (Pt 5, Ch 1).
(e) Lateral vibration for shafting systems which include cardan shafts (Pt 5,Ch 3).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with.

(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard.
The design is to consider both static ($<10^3$ cycles) and dynamic loading conditions.
(c) Under dynamic operating conditions, the gear is to be considered for:
  (i) design maximum dynamic duty steering torque;
  (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(d) Under a static duty ($<10^3$ load cycles) steering torque, which should be not less than M_T, as defined in 4.3.1.
(e) The following minimum factor of safety values are to be achieved:
Surface Stress S_{Hmin} = 1,0.
Bending Stress S_{Fmin} = 1,5.
(f) For hydraulic pressure retaining parts and load bearing components, *see also* Pt 6, Ch 1.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 3.2.10 in Vol 1, Pt 3, Ch 3, is to be determined as follows:

$$d_{SU} = 26{,}03 \sqrt[3]{(V + 3)^2 A_N X_{PF}} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from Table 3.2.6 in Vol 1, Pt 3, Ch 3

The corresponding maximum turning moment, M_T, is to be determined as follows:

$$M_T = 11{,}1 \times d_{SU}{}^3 \quad \text{Nmm}$$

4.3.2 In addition to the requirements of Volume 1, Part 3 the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x–x is not less than:

$$Z = 1{,}73 \sqrt{(V + 3)^4 A_N{}^2 X_{PF}{}^2 + \frac{a^2}{4} T_M{}^2\, 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 3.4.1

T_M = maximum thrust of the thruster unit, in tonnes.

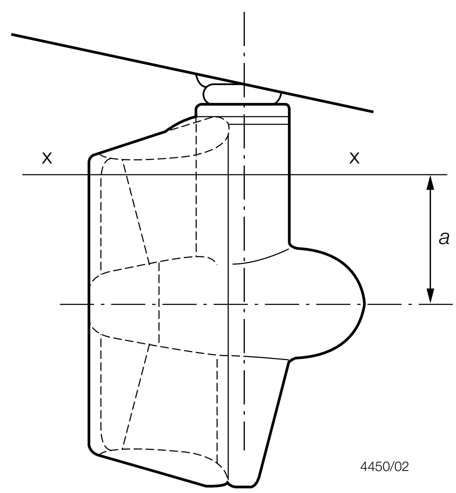


Fig. 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered ships, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in Pt 7, Ch 1.

5.1.2 The specific requirements for lubricating/ hydraulic oil systems and standby arrangements are given in Pt 7, Ch 3.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 9, Ch 1.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 3.6.1.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see* 6.2.2
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

6.2.2 An indication of the angular position of the azimuth thruster(s), the direction of thrust, an indication representative of the magnitude of thrust and an indication of the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 The alarms described in Table 3.6.1 are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Pt 9, Ch 1.

■ *Section 7* Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of 7.2 to 7.4.

7.1.2 Where the thruster units are electrically driven the relevant requirements, including surveys, of Pt 10, Ch 1 are to be complied with.

7.2 General arrangements

7.2.1 Where a central power generation system is employed the requirements of Pt 10, Ch 1, 15.2.5 are to be complied with.

7.2.2 For azimuth thrusters the generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained within a period not exceeding 45 seconds, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively when the electrical requirements may be met by one generating set in operation, on loss of power, the automatic starting and connecting to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

7.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

7.3 Distribution arrangements

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, convertors, protective devices or control circuits.

7.4 Auxiliary supplies

7.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) the voltage regulation and current sharing requirements defined in Pt 10, Ch 1,8.4.2 and 8.4.7 are to be maintained over the full range of power factors that may occur in services;

(b) auxiliary equipment and services are to operate with any waveform distortion introduced by convertors without deleterious effect. (This may be achieved by the provision of suitably filtered/converted supplies).

Section

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to podded propulsion units where used for propulsion, DP duty or as the sole means of steering.

1.1.2 For the purposes of these Rules, a podded propulsion unit is any propulsion or manoeuvring device that is external to the normal form of the ship's hull and houses a propeller powering device.

1.1.3 The requirements of this Chapter relate to podded propulsion units powered by electric propulsion motors. Podded propulsion units with other drive arrangements will be subject to individual consideration.

1.1.4 The structural requirements stated in 5.1, 5.2 and 5.3 relate to podded propulsion units having a conventional cylindrical pod body with single supporting strut with or without an integral slewing ring arrangement, *see* Fig. 4.1.1. Novel and unconventional arrangements will be subject to individual consideration. In such cases, the designers are advised to contact LR in the early stages of the design for advice on the manner and content of design information required for formal classification appraisal.

1.1.5 The aft end structures associated within podded installations are to be examined in respect of potential slamming with reference to Vol 1, Pt 5, Ch 3,4.

1.1.6 Attention is to be given to any relevant requirements of the Naval authority.

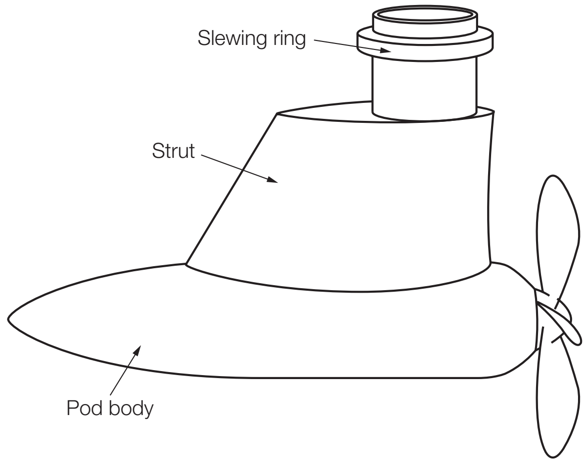


Fig. 4.1.1 Podded propulsion unit

■ *Section 2* General requirements

2.1 Pod arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two podded propulsion units are to be provided where these form the sole means of propulsion. For vessels where a single podded propulsion unit is the sole means of propulsion, an evaluation of a detailed engineering and safety justification will be conducted by LR, *see* 2.2.2. This evaluation process will include the appraisal of a Failure Modes and Effects Analysis (FMEA) to verify that sufficient levels of redundancy and monitoring are incorporated in the podded propulsion unit's essential support systems and operating equipment.

2.2 Plans and information to be submitted

2.2.1 In addition to the plans required by Pt 3, Ch 1 and Ch 2, Pt 4, Ch 1, Pt 5, Pt 6, Ch 1, Pt 7, Ch 3 and Parts 9 and 10, the following plans and information are required to be submitted for appraisal:

(a) Description of the ship's purpose/capabilities together with the pod's intended operational modes in support of these capabilities. The operational modes are to include stopping the vessel and restrictions on steering angles at different ship speeds. *See also* (f).
(b) Power transmitted at MCR condition (shaft power and rpm) and other maximum torque conditions, e.g. bollard pull.
(c) Details of the electric propulsion motor short-circuit torque and motor air gap tolerance.
(d) Sectional assembly in the Z-X plane, *see* Fig. 4.2.1.
(e) Specifications of materials and NDE procedures for components essential for propulsion and steering operation, *see* 4.1.

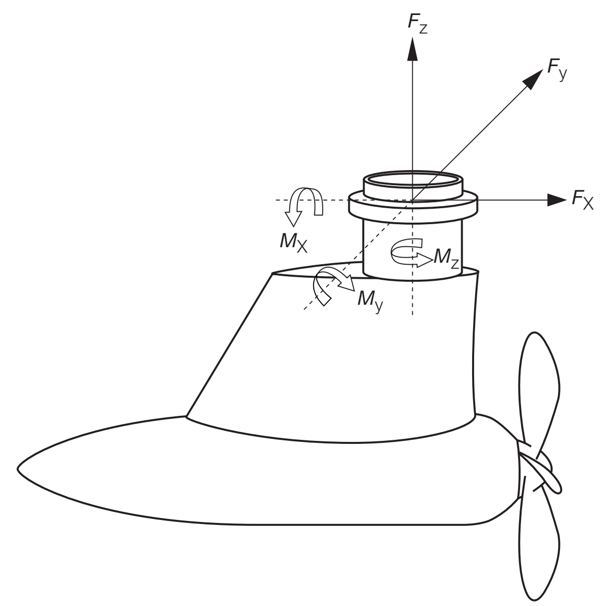


Fig. 4.2.1 Pod co-ordinate system

(f) Details of intended manoeuvring capability of the ship in each operating condition. (To be declared by the Naval Authority, *see also* 3.1.1).
(g) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes (*see* 2.4.1, 6.3.7, 6.6.5 and 6.6.6).
(h) Supporting calculations and direct calculation reports.
(j) Structural component details including: strut, pod body, bearing supports, bearing end caps, ship's structure in way of podded propulsion unit integration and a welding Table showing a key to weld symbols used on the plans specifying weld size, type, preparation and heat treatment. The information should include the following:
- Detailed drawings showing the structural arrangement, dimensions and scantlings.
- Welding and structural details.
- Connections between structural components (bolting).
- Casting's chemical and mechanical properties.
- Forging's chemical and mechanical properties.
- Material grades for plate and sections.

(k) Nozzle ring structure and nozzle support details.
(l) Propeller shaft bearing mounting and housing arrangement details, *see also* 6.3.6.
(m) Details of propeller shaft and steering bearings, where roller bearings are used supporting calculations are to be submitted, see 6.3.7 and 6.6.6.
(n) Propeller shaft seal details.
(o) Details of propeller shaft and pod steering securing/locking and means of aligning the securing/locking arrangements.
(p) Cooling systems piping system schematic.
(q) Details of any lubricating oil conditioning systems (filtering/cooling/heating) and control arrangements necessary to ensure the continuous availability of the required lubricating oil quality to the propeller shaft bearings.
(r) Details of installed condition monitoring equipment.
(s) Details of the derivation of any duty factor used in the design of the steering gears.
(t) Recommended installation and maintenance procedures. This is to include any in-water/underwater engineering procedures where recommended by the pod manufacturer.
(u) Identification of any potentially hazardous atmospheric conditions together with details of how the hazard will be countered, this should include a statement of the maximum anticipated air temperature within the pod during full power operation, *see* 2.3.
(v) Access and closing arrangements for pod unit inspection and maintenance.
(w) Heat balance calculations for the pod unit taking into account electrical thermal riser when the pod is operating at maximum continuous operating conditions, heat transfer and maximum sea-water/air temperatures, *see* 6.7.4.
(x) Details of proposed testing and trials required by Section 9.
(y) Details of emergency steering and pod securing arrangements, *see* 6.6.8.

2.2.2 Where an engineering and safety justification report is required, the following supporting information is to be submitted:
- A Failure Mode and Effects Analysis (FMEA), *see* 2.5.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3 Pod internal atmospheric conditions

2.3.1 Machinery and electrical equipment installed within the pod unit are to be suitable for operation, without degraded performance, at the maximum anticipated air temperature and humidity conditions within the pod unit with the pod operating at its maximum continuous rating in sea water of not less than 32°C.

2.3.2 Precautions are to be taken to prevent as far as reasonably practicable the possibility of danger to personnel and damage to equipment arising from the development of hazardous atmospheric conditions within the pod unit. Circumstances that may give rise to these conditions are to be identified and the counter measures taken are to be defined.

2.4 Global loads

2.4.1 The overall strength of the podded propulsion unit structure is to be based upon the maximum anticipated in-service loads, including, where necessary, the effects from ship motion (*see* Table 3.2.1 in Vol 1, Pt 5, Ch 3). The designer is to supply the following maximum load and moment values to which the unit may be subjected with a description of the operating condition at which they occur:
- F_x, Force in the longitudinal direction;
- F_y, Force in the transverse direction;

- F_z, self weight, in water, augmented by the ship's pitch and heave motion and flooded volume where applicable, *see* 5.3.3 and Vol 1, Pt 5, Ch 3;
- M_x, moment at the slewing ring about the pod unit's global longitudinal axis;
- M_y, moment at the slewing ring about the pod unit's global transverse axis;
- M_z, moment at the slewing ring about the pod unit's vertical axis (maximum dynamic duty steering torque on steerable pods).

The directions of the X, Y and Z axes, with the origin at the centre of the slewing ring, are shown in Fig. 4.2.1.

2.4.2 Where the maximum loads and moments described in 2.4.1 cannot be readily identified or are based on model testing, the loads and moments are to be stated at pod unit steering angular intervals of 5 degrees over the range from ahead to astern.

2.4.3 Where control systems are installed to limit the operation of the podded drive to defined angles at defined ship speeds, this information may be taken into consideration when determining the pod unit loading.

2.4.4 Where pod units are fixed about their Z axis, then maximum global loads, to be used as the basis of the structural appraisal, are to be determined for inflows in 5 degree increments between the extremes of anticipated inflow angle during manoeuvring with ship at full speed and maximum propeller thrust.

2.5 Failure Modes and Effects Analysis (FMEA)

2.5.1 An FMEA is to be carried out where a single podded propulsion unit is the vessel's sole means of propulsion, *see* 2.1.1. The FMEA is to identify components where a single failure could cause loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.5.2 The FMEA is to be carried out using the format presented in Table 2.17.1 in Vol 2, Pt 1, Ch 2 or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812. *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.5.3 The FMEA is to be organized in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analyzed to determine the effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.5.1.

2.5.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.5.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analyzed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.5.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.6 Ice Class requirements

2.6.1 Where an ice class notation is included in the class of a ship, additional requirements as detailed in Vol 3, Pt 1, Ch 1 are to be complied with as applicable.

■ *Section 3* Functional capability

3.1 General

3.1.1 The arrangement of podded propulsion units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the propeller in the ahead condition at the declared steering angles and sea conditions.
(b) Manoeuvring speeds of the propeller shaft in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Vol 2, Pt 1, Ch 2.
(d) All astern running conditions for the ship.
(e) Manoeuvring in ice where ice class is required.

3.1.2 In general, the steering mechanism is to be capable of turning the pod between the declared steering angle limits at an average rotational speed of not less than 0,4 rev/min with the ship operating at its maximum ahead service speed.

3.1.3 The steering mechanism for podded units used for Dynamic Positioning applications with an associated class notation, is to be capable of a rotational speed of not less than 1,5 rev/min.

■ *Section 4* Materials

4.1 General

4.1.1 The specification for materials required by 2.2.1(e) is to cover the pod body, strut, gearing, shafts, couplings and propeller, with details of chemical composition, heat treatment and mechanical properties. Where a combination of different materials is proposed for the structural arrangement, LR is to be advised in the early stages of the design process to identify material and NDE requirements.

4.1.2 The materials used for the major structural and machinery components of the podded drive unit are to be manufactured and tested in accordance with the requirements of Vol 1, Part 2. Materials for which provision is not made therein may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

4.1.3 Materials for machinery and system components are also to comply with the requirements from the relevant chapters of the Rules.

4.1.4 Where load carrying threaded fasteners screw directly into structural castings, the material integrity of the casting is to be such that there is no porosity in the area of the connection.

4.1.5 Castings and forgings are to be subject to non-destructive examination in accordance with the relevant sections of the Rules for Materials.

4.1.6 For components of novel design, the material test and non-destructive examination requirements will be subject to evaluation by LR.

■ *Section 5* Structure design and construction requirements

5.1 Pod structure

5.1.1 Podded unit struts and pod bodies may be of cast, forged or fabricated construction or a combination of these construction methods.

5.1.2 Means are to be provided to enable the propeller shaft, bearings and seal to be fully examined at docking Survey.

5.1.3 When high tensile steel fasteners are used as part of the structural arrangement and there is a risk that these fasteners may come into contact with sea-water, carbon-manganese and low alloy steels with a specified tensile strength of greater than 950 N/mm^2 are not to be used due to the risk of hydrogen embrittlement.

5.1.4 For steerable pod units, an integral slewing ring is to be arranged at the upper extremity of the strut to provide support for the slewing bearing.

5.1.5 The strut is to have a smooth transition from the upper mounting to the lower hydrodynamically adapted sectional shapes.

5.1.6 Vertical and horizontal plate diaphragms are to be arranged within the strut and, where necessary, secondary stiffening members are to be arranged.

5.1.7 Pod unit structure scantling requirements are shown in Table 4.5.1. Where the scantling requirements in Table 4.5.1 are not satisfied, direct calculations carried out in accordance with Section 5.3 may be considered.

5.1.8 The connection between the strut and the pod body should generally be effected through large radiused fillets in cast pod units or curved plates in fabricated pod units.

5.1.9 The structural response under the most onerous combination of loads is not to exceed the operational requirements of the propulsion or steering system components.

5.2 Hull support structure

5.2.1 For supporting the main slewing bearing outer races, a system of primary structural members is to be provided in order to transfer the maximum design loads and moments from the podded propulsion unit into the ship's hull without undue deflection. Due account is also to be taken of the loads induced by the maximum ship's motions in the vertical direction resulting from combined heave and pitch motion of the ship.

5.2.2 The hull support structure in way of the slewing bearing should be sufficiently stiff that the bearing manufacturer's limits on seating flatness are not exceeded due to hull flexure as a consequence of the loads defined under 5.2.1.

5.2.3 Generally, the system of primary members is to comprise a pedestal girder directly supporting the slewing ring and bearing. The pedestal girder is to be integrated with the ship's structure by means of radial girders and transverses aligned at their outer ends with the ship's bottom girders and transverses, *see* Fig. 4.5.1. Proposals to use alternative arrangements that provide an equivalent degree of strength and rigidity may be submitted for appraisal.

5.2.4 The ship's support structure in way of the podded unit may be of double or single bottom construction. Generally, podded drives should be supported where practical within a double bottom structure; however final acceptance of the supporting arrangements will be dependent upon satisfying the stress criteria set out in Table 4.5.2, *see also* 5.3.5.

Table 4.5.1 Podded propulsion unit structural requirements

Location	Requirement	Notes
Strut external shell plating	Thickness, in mm, is to be not less than: $t = 0{,}0063s\ f\ (h_7\ k)^{0,5}$	The minimum thickness of plating diaphragms and primary webs within the strut is to be not to less than the Rule requirement for the strut external plating. For internal diaphragms, panel stiffening is to be provided where the ratio of spacing to plate thickness (*s/t*) exceeds 100. Where there are no secondary members, *s* is to be replaced by *S*.
Strut primary framing	The section modulus in cm^3 is to be not less than: $z = 7{,}75h_7\ l_e^2\ S\ k$	This does not apply to full breadth plate diaphragms.
Strut secondary stiffening	The section in cm^3 is to be not less than: $z = 0{,}0056h_7\ l_e^2\ s\ k$	This does not apply to full breadth plate diaphragms.
Cylindrical pod body external shell plating	Thickness, in mm, is to be not less than: $t = 3{,}0R_g\ (h_7\ k)^{0,5}$	
Symbols		
f = panel aspect ratio correction factor = $[(1{,}1 - s/(2500S)]$ h_7 = $(T + C_w + 0.014V^2)$ k = local higher tensile steel factor, as in Vol 1, Pt 6, Ch 2 l_e = effective span of the member under consideration, in metres s = the frame spacing of secondary members, in mm C_w = design wave amplitude, in metres, as in Table 3.2.1 in Vol 1, Pt 5, Ch 3 R_g = mean radius of pod body tube, in metres S = the spacing of primary members, in metres T = the vessel scantling draft, in metres, as in Vol 1, Pt 3, Ch 1,5.2 V = maximum design speed, in knots, as in Vol 1, Pt 3, Ch 3,2.11		

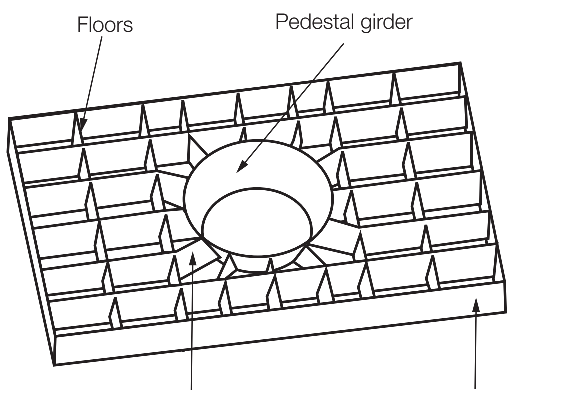


Fig. 4.5.1 Hull support structure

5.2.5 The shell envelope plating and tank top plating in way of the aperture for the podded drive (i.e. over the extent of the radial girders shown in Fig. 4.5.1) is to be increased by 50 per cent over the Rule minimum thickness to provide additional local stiffness and robustness. However the thickness of this plating is not to be less than the actual fitted thickness of the surrounding shell or tank top plating.

5.2.6 The scantlings of the primary support structure in way of the podded drive are to be based upon the limiting design stress criteria specified in Table 4.5.2, *see also* 5.3.5. Primary member scantlings are, however, not to be less than those required by Vol 1, Pt 6, Ch 3, 7 and 8.

5.2.7 The pedestal girder is to have a thickness not less than the required shell envelope minimum Rule thickness in way. Where abutting plates are of dissimilar thickness then the taper requirements of Vol 1, Pt 6, Ch 4 are to be complied with.

5.2.8 In general, full penetration welds are to be applied at the pedestal girder boundaries and in way of the end connections between the radial girders and the pedestal girder. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0,34.

5.3 Direct calculations

5.3.1 Finite element or other direct calculation techniques may be employed in the verification of the structural design. The mesh density used is to be sufficient to accurately demonstrate the response characteristics of the structure and to provide adequate stress and deflection information. A refined mesh density is to be applied to geometry transition areas and those locations where high localised stress or stress gradients are anticipated.

Table 4.5.2 Direct calculation maximum permissible stresses

Permissible stress values		
Location	Podded drive structure	Podded drive/hull interface
X-Y shear stress	$0{,}26\sigma_o$	$0{,}35\sigma_o$
Direct stress due to bending	$0{,}33\sigma_o$	$0{,}63\sigma_o$
Von Mises stress	$0{,}40\sigma_o$	$0{,}75\sigma_o$
Localised Von Mises peak stresses	σ_o	σ_o
Symbols		
σ_o = minimum yield strength of the material		
NOTES 1. The values stated above are intended to give an indication of the levels of stress in the pod and ship structure for the maximum loads which could be experienced during normal service. 2. If design is based on extreme or statistically low probability loads, then proposals to use alternative acceptance stress criteria may be considered.		

5.3.2 Model boundary constraints are generally to be applied in way of the slewing ring/ship attachment only.

5.3.3 The loads applied to the mathematical model, *see* 2.4.1, are to include the self weight, dynamic acceleration due to ship motion, hydrodynamic loads, hydrostatic pressure, propeller forces and shaft bearing support forces. In situations where a pod can operate in the flooded condition or where the flooding of a pod adds significant mass to the pod, details are to be included.

5.3.4 Based on the most onerous combination of loading conditions, the stress criteria shown in Table 4.5.2 are not to be exceeded.

5.3.5 Where the structural design is based on a fatigue assessment and the stress criteria shown in Table 4.5.2 are not applicable, details of cumulative load history and stress range together with the proposed acceptance criteria are to be submitted for consideration.

■ *Section 6* Machinery design and construction requirements

6.1 General

6.1.1 The requirements detailed in Pt 1, Ch 2 are applicable.

6.2 Gearing

6.2.1 If gearing is used in the propulsion system then the requirements of Pt 3, Ch 1 are applicable.

6.3 Propulsion shafting

6.3.1 In addition to meeting the requirements of Pt 3, Ch 2 and Part 5, the pod propulsion shafting supporting an electric motor is to be sufficiently stiff that both static and dynamic shaft flexure are within the motor manufacturer's limits for all envisaged operating conditions.

6.3.2 Critical motor speeds which may result in significant vibration amplitudes are to be sufficiently removed from the shaft running speed that there will be no significant lateral vibration response within ± 20 per cent of the running speed.

6.3.3 As an alternative to the requirements of Pt 3, Ch 2, a fatigue strength analysis of shafting components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criterion may be submitted for consideration. The effects of stress concentrations, material properties and operating environment are to be taken into account.

6.3.4 With the exception of the propeller connection (requirements stated in Pt 4, Ch 1) couplings relying on friction are to have a factor of safety of 2,5 against slippage at the maximum rated torque. In order to reduce the possibility of fretting, a grip stress of not less than 20 N/mm^2 is to be attained.

6.3.5 The effects of motor short-circuit torque on the shafting system should not prevent continued operation once the fault has been rectified.

6.3.6 The arrangement of shaft bearings is to take account of shaft thermal expansion, misalignment of bearings, shaft slope through the bearings and manufacturing tolerances.

6.3.7 Propeller shaft roller bearing life calculations are to take account of the following loadings:

- Shaft, motor, propeller and other shaft appendages' weights;
- Forces due to ship's motion;
- Offset thrust loads from the propeller;
- Side loads on propeller;
- Variance of thrust, thrust offset and side load with pod azimuth angle. This load variance should take account of the motor control characteristics;
- Forces due to pod rotation, including gyroscopic forces;
- A predicted azimuth service profile for the pod indicating the proportion of time spent at various azimuth angles;
- Loads due to hydrodynamic interaction between pods;
- Any additional loads experienced during operation in ice conditions (for Ice Class notations);
- Where validation of the above loadings is available, detailed calculations must demonstrate that the bearing life when operating at the normal duty profile will comfortably exceed the time between 6-yearly surveys. Parameters used to justify the bearing life, i.e. those related to oil cleanliness, viscosity limits and material quality are to be quoted.

6.3.8 Where detailed validation of the loadings identified in 6.3.7 is not available the calculations for roller bearings are to indicate a bearing life greater than 65,000 hours at the maximum continuous rating of the podded drive taking into account the azimuth angle duty cycle. Any parameters used to justify this life, i.e. those related to oil cleanliness, water contamination and viscosity limits are to be quoted. Proposals for the use of a shaft bearing of life less than 65,000 hours will be considered on application with details of alleviating factors and supporting documentation, however this bearing life must exceed the time between surveys.

6.3.9 Means are to be provided for detecting shaft bearing deterioration. Where rolling element shaft bearings are used in single pod applications or in pods where the motor power exceeds 6 MW, vibration monitoring of the shaft bearings is to be provided The bearing monitoring system is to be suitable for the local bearing conditions and is to be able to differentiate from other vibration sources such as propeller cavitation or ship motions.

6.3.10 On multi podded ships, means are to be provided to hold the propeller on an inoperable unit stationary whilst the other pod(s) propel the vessel at manoeuvring speed. Operating instructions displayed at the holding mechanism's operating position are to include a direction to inform the bridge of any limitation in ships speed required as a result of the holding mechanism being activated.

6.3.11 Shaft seals for maintaining the watertight integrity of the pod are to be Type Approved to a standard acceptable to LR. The seals are to be designed to withstand the extremes of operation for which they are intended and this is to include extremes of temperature, vibration, pressure and shaft movement.

6.3.12 In single pod installations, the integrity of shaft seals is to be evaluated on the basis of a double failure. In such installations, seal duplication is to be used with indication of failure of one seal being provided.

6.4 Propeller

6.4.1 The requirements of Pt 4, Ch 1 are to be complied with.

6.4.2 Where propeller scantlings have been determined by a detailed fatigue analysis, based on reliable wake survey data as described in Pt 4, Ch 1,7.1.6, a factor of safety of 1,5 against suitable fatigue failure criteria is to be demonstrated. The effects of fillet stress concentrations, residual stress, fluctuating loads and material properties are to be taken into account.

6.5 Bearing lubrication system

6.5.1 The bearing lubrication system is to be arranged to provide a sufficient quantity of lubricating oil of a quality, viscosity and temperature acceptable to the bearing manufacturer under all ship operating conditions.

6.5.2 In addition to the requirements detailed in this Section, the requirements of Pt 7, Ch 3,8 as applicable are to be complied with.

6.5.3 The sampling points required by Pt 7, Ch 3,8.9 are to be located such that the sample taken is representative of the oil present at the bearing.

6.5.4 Where continuous operation of the lubricating oil system is essential for the pod to operate at its maximum continuous rating, a standby pump in accordance with Pt 7, Ch 3,8.2.2 is to be provided. In such systems, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the pod.

6.5.5 Where bearings are grease lubricated, means are to be provided for collecting waste grease to enable analysis for particulates and water. The arrangements for collecting waste grease are to be in accordance with the pod manufacturer's recommendations.

6.5.6 Pipework conveying lubricating oil is to be sited such that any possible leakage from joints will not impinge on electrical equipment, hot surfaces or other sources of ignition, *see also* Pt 7, Ch 2,2.8.2.

6.6 Steering system

6.6.1 The requirements of Pt 6, Ch 1, Sections 1, 2, 3, 4, 5, 8 and 9 are to be complied with where applicable. *See also* 3.1.

6.6.2 For vessels where a single podded propulsion unit is the sole means of propulsion, the requirement for auxiliary steering gear in Pt 6, Ch 1,4 is to be achieved by means of two or more identical power units.

6.6.3 Steering arrangements, other than of the hydraulic type, may be accepted provided that there are means of limiting the maximum torque to which the steering arrangement may be subjected.

6.6.4 The steering mechanism is to be provided with power that is sufficient for the maximum steering torques present during the declared functional capability identified in 3.1 and is to be demonstrated for the most onerous specified manoeuvring trial, *see* Section 9.

6.6.5 Geared arrangements employed for steering are to consider the following conditions:

- A design maximum dynamic duty steering torque, M_z, *see* 2.4.1;
- A static duty (≤10^3 load cycles) steering torque. The static duty steering torque should not be less than M_W, the maximum torque which can be generated by the steering gear mechanism.

The minimum factors of safety, as derived using ISO 6336 Calculation of load capacity of spur and helical gears, or a recognized national standard, are to be 1.5 on bending stress and 1,0 on Hertzian contact stress. The use of a duty factor in the dynamic duty strength calculations is acceptable but the derivation of such a factor, based on percentage of time spent at a percentage of the maximum working torque, should be submitted to LR for consideration and acceptance.

6.6.6 Slewing ring bearing capacity calculations are to take account of:

- Pod weight in water;
- Gyroscopic forces from the propeller and motor;
- Hydrodynamic loads on pod; and
- Forces due to ship's motions.

The calculations are to demonstrate that the factor of safety against the maximum combination of the above forces is not less than 2. The calculations are to be carried out in accordance with a suitable declared standard.

6.6.7 Means of allowing the condition of the slewing gears and bearings to be assessed are to be provided.

6.6.8 On multi podded ships, means are to be provided to secure each pod unit's slewing mechanism in its mid position in the event of a steering system failure. These arrangements are to be of sufficient strength to hold the pod in position at the ship's manoeuvring speed. Operating instructions displayed at the securing mechanism's operating position are to include a direction to inform the bridge of any limitation in ships speed required as a result of the securing mechanism being activated.

6.7 Ventilation and cooling systems

6.7.1 Means are to be provided to ensure that air used for motor cooling purposes is of a suitable temperature and humidity as well as being free from harmful particles.

6.7.2 Cooling water supplies are to comply with Pt 7, Ch 3,7. *See also* Pt 10, Ch 1,8.6.1.

6.7.3 On single podded installations, a standby cooling arrangement of the same capacity as the main cooling system, is to be provided and available for immediate use.

6.7.4 For pods having an electric propulsion motor but no active cooling system, heat balance calculations as required by 2.2.1(w) are to demonstrate that the pod unit and associated systems are able to function satisfactorily over all operating conditions, *see* Pt 1, Ch 2,4.4.

6.8 Pod drainage requirements

6.8.1 Unless the electrical installation is suitable for operation in a flooded space, means are to be provided to ensure that leakage from shaft bearings or the propeller seal do not reach the motor windings, or other electrical components. Account is to be taken of cooling air flow circulating within the pod unit.

6.8.2 Two independent means of drainage are to be provided so that liquid leakage may be removed from the pod unit at all design angles of heel and trim, *see* Pt 1, Ch 2,4.5.

6.8.3 Pipework conveying leakage from the pod is to be sited such that any leakage from joints will not impinge on electrical equipment, *see also* Pt 7, Ch 2,2.8.2.

6.9 Hydraulic actuating systems

6.9.1 Hydraulic actuating systems are to comply with Pt 6, Ch 1,5 and Pt 7, Ch 5,11 as applicable.

■ *Section 7* Electrical equipment

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Pt 10, Ch 1.

7.1.2 Means are to be provided to prevent electrical currents flowing across shaft bearings, which may cause their premature failure.

7.1.3 Steering gear electrical systems are to comply with Pt 6, Ch 1,7.

■ *Section 8* Control engineering arrangements

8.1 General

8.1.1 Control engineering arrangements are to be in accordance with Pt 9, Ch 1.

8.1.2 Steering gear control, monitoring and alarm systems are to comply with Pt 6, Ch 1,6 and Ch 1,7.

8.1.3 Steering control is to be provided for podded drives from the navigating bridge, the main machinery control station and locally.

8.1.4 An indication of the angular position of the podded propulsion unit(s) and the magnitude of the thrust is to be provided at each station from which it is possible to control the direction of thrust. This indication is to be independent of the steering control system.

8.1.5 Means are to be provided at the remote control station(s), independent of the podded drive control system, to stop each podded drive in an emergency. *See also* Pt 10, Ch 1,15.3.7.

8.1.6 Where programmable electronic equipment is used to prevent loads exceeding those for which the system has been designed (*see* 2.4.3), then either:

(a) A fully independent hard wired backup is to be provided;
or

(b) The software is to be certified in accordance with LR's Software Conformity Assessment System – Assessment Module GEN1 (1994) and have an independent solution showing redundancy with design diversity, etc., *see* Pt 9, Ch 1,2.11 of the Rules.

8.2 Monitoring and alarms

8.2.1 The requirements for alarms and monitoring arrangements are to be in accordance with Pt 6, Ch 1,8.1 and Table 4.8.1.

8.2.2 Alarms specified in Table 4.8.1 are to be in accordance with the alarm system specified by Pt 9, Ch 1,2.3.

8.2.3 Sensors for control, monitoring and alarm systems required by the Rules and located within the pod are to be duplicated in order that a single sensor failure does not inhibit system functionality.

8.2.4 Pod unit bilge pumping arrangements are to function automatically in the event of a high liquid level being detected in the pod unit.

8.2.5 The number and location of bilge level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

Table 4.8.1 Specific alarms for pod control systems

Item	Alarm	Note
Podded drive azimuth angle	—	Indicator, *see* 8.1.4
Propulsion motors	Overload, power failure	To be indicated on the navigating bridge
Hydraulic oil system pressure	Low	To be indicated on the navigating bridge
Lubricating oil supply pressure	Low	If separate forced lubrication for shaft bearings; to be indicated on the navigating bridge
Lubricating oil temperature	High	
Lubricating oil tank level for motor bearings	Low	
Water in lubricating oil for motor bearings	High	Required for single podded propulsion units only
Motor cooling air inlet temperature	High	
Motor cooling air outlet temperature	High	
Motor cooling air flow	Low	
Shaft bearing vibration monitoring	High	*See* 6.3.8. Monitoring is to allow bearing condition to be gauged using trend analysis
Bilge pump operation	Abnormal	Alarm set to indicate a frequency or duration exceeding that which would normally be expected
Bilge level	High	

Section 9
Testing and trials

9.1 General

9.1.1 The following requirements are to be complied with:

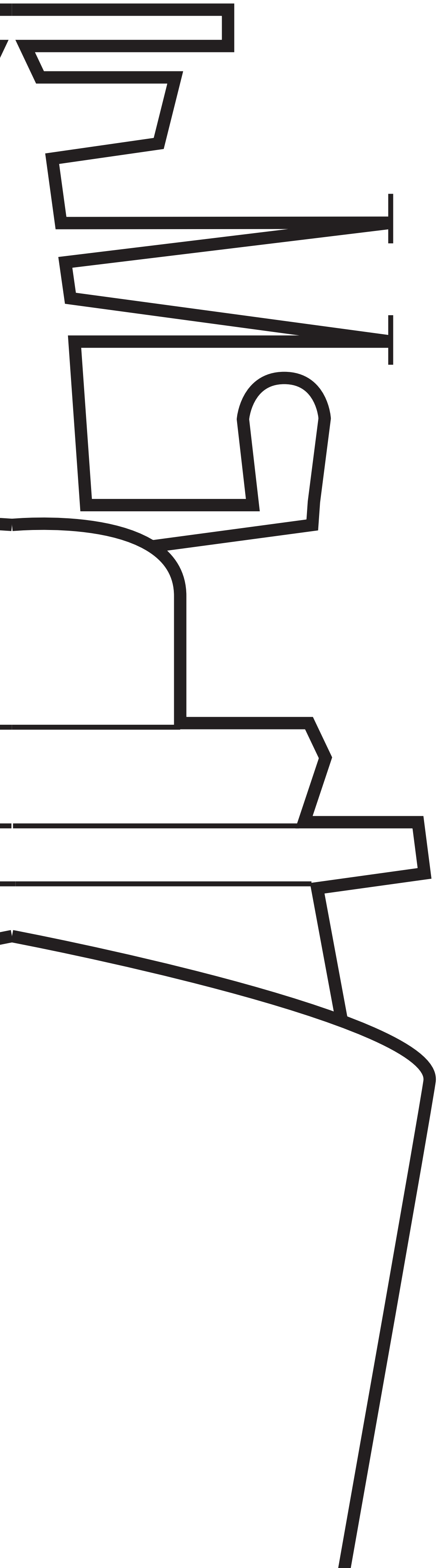
- Pt 1, Ch 2,16 for sea trials.
- Pt 1, Ch 2,15 for steering trials.

In addition, the functional capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.1.3 Electric motor cooling systems are to be verified, as far as possible, to ensure that they are capable of limiting the extremes of ambient temperature to those specified in 2.3.1.

9.1.4 Any trials and testing identified from the FMEA report, *see* 2.5.4(f), are also to be carried out.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 5*

Shaft vibration and alignment

January 2005

Lloyd's Register

Chapter Contents

Volume 2, Part 5

Contents

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 1, 2, 3 and 4.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.6 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognized techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

Table 1.3.1 C_k factors

For intermediate shafts with			For thrust shafts external to engines		For propeller shafts
Integral coupling flanges	Shrink fit couplings	Keyways	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	For which k = 1,22 and = 1,26
1,0	1,0	0,60	0,85	0,85	0,55

NOTE
The determination of C_k – factors for shafts other than shown in this Table is at the discretion of LR.

■ Section 3
Design

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm
r = ratio N/N_s or N_c/N_s whichever is applicable
N = engine speed, in rev/min
N_c = critical speed, in rev/min
N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
Q_s = rated full load mean torque
τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2
τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
C_k = a factor for different shaft design features, *see* Table 1.3.1
C_d = a size factor defined as 0,35 + 0,93$d^{-0,2}$
k = the factor used in determining minimum shaft diameter, defined in Pt 3, Ch 2,4.2.1 and 4.4.3.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0,9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1,38 \text{ for } 0,9 \le r < 1,05 \quad \text{N/mm}^2$$

$$\tau_t = \pm\, 1,7\tau_c \frac{1}{\sqrt{C_k}} \quad \text{for } r \le 0,8$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of Pt 3, Ch 2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of 0,95N_s and 1,05N_s the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0{,}014d) \quad \text{N/mm}^2$$

3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5{,}5\tau_c$$

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to ±2,0Q_s in general, or to ±2,5Q_s for close-coupled revolving field alternating current generators, over the speed range from 0,95N_s to 1,05N_s. Below 0,95N_s the amplitudes are to be limited to ±6,0Q_s. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from 0,95N_s to 1,05N_s flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.2.3.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of 3.3.1, 3.3.2 and 3.3.3 are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between 0,85N_s and 1,05N_s are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of 2.2. The vibratory torque should not exceed one-third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

3.6.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_c.

3.6.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$\frac{16}{18 - r} N_c \text{ to } \frac{18 - r}{16} N_c \text{ inclusive.}$$

3.6.4 Where calculated vibration stresses due to criticals below 0,8N_s marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_c, having regard to tachometer accuracy.

3.6.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.8 For excessive vibratory torque, stress or amplitude in other components, bases on 3.6.1 to 3.6.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.9 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the maximum service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 1, 2, 3 and 4.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, P, in kW, and revolutions per minute, R, are referred to, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg

= $0{,}785\,(D^2 - d^2)\,Gl$

M = dry mass of propeller, in kg

$A = \dfrac{m}{M}$

$M_e = M\,(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in 2.2.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0{,}98}{n}\left(\frac{ab}{a+b}\right)^{1/2} \text{ rev/min}$$

where

$$a = \frac{E}{Gl^2}\,(66{,}2 + 97{,}5A - 8{,}88A^2)^2 \text{ c/min}^2$$

$$b = 91{,}2\,\frac{k}{M_e} \text{ c/min}^2$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the maximum service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4*
Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

Section

Section 1 General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 1, 2, 3 and 4.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.1.4 For shafting enclosed within a gearbox, *see* Pt 3, Ch 1.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Pt 2, Ch 1.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Pt 1, Ch 2,4.3.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

Section 2 Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in 2.1.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

Section 3 Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 1, 2, 3 and 4.

1.1.2 Unless otherwise advised, it is the responsibility of the Builders as main contractor to ensure, in co-operation with the Enginebuilders that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Basic requirements

1.2.1 For main propulsion installations, the shafting is to be aligned to give reasonable bearing reactions and bending moments, and to meet any specified coupling conditions at the forward end of the shafting at all conditions of vessel loading and operation. The Builder is to position the bearings and construct the bearing seatings to minimize the effects of movements under all operating conditions.

1.2.2 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2.3 Calculations for single engine geared installations having a screwshaft diameter less than 300 mm are not required.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted for approval – Shaft alignment calculations

2.1.1 Shaft alignment calculations are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') for approval for the following shafting systems where the screwshaft has a diameter of 250 mm or greater in way of the aftermost sterntube bearing:

(a) All geared installations.
(b) Installations with one bearing, or less, inboard of the forward sterntube bearing.
(c) Where prime movers or shaftline bearings are installed on resilient mountings.

2.1.2 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the ship's operating draught;
(c) effect of predicted hull deformations over the range of the ship's operating draught, where known;
(d) gear forces, where appropriate;
(e) for multi-engined installations, possible contributions in the mode of operation;
(f) propeller offset thrust effects;
(g) bearing loading in the horizontal plane, where appropriate; and
(h) bearing weardown, where applicable; and its effect on the bearing loads.

2.1.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust effects, where applicable;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft coupling of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;
(g) origin of findings where the effect of hull deformation has been considered, *viz.* whether finite element calculations or measured results from sister or similar ships have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(j) the manufacturer's allowable bearing loads.

2.2 Particulars to be submitted for review – Shaft alignment procedure

2.2.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;

(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;
(j) proposed bearing load measurement technique and its estimated accuracy;
(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(l) proposed shaft alignment acceptance criteria, including the tolerances; and
(m) flexible coupling alignment criteria.

2.3 Design and installation criteria

2.3.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of ship loading and machinery operation, bearing load distribution satisfying the requirements of 2.3.2.

2.3.2 Design and installation of the shafting is to satisfy the following criteria:
(a) The Builder is to position the bearings and construct the bearing seatings to minimize the effects of hull deflections under any of the ship's operating conditions.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.
(c) Sterntube bearing loads are to satisfy the requirements of Pt 3, Ch 2,4.16.
(d) Intermediate shaft bearings' load s are not to exceed 80 per cent of the bearing manufacturer's allowed maximum load for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gearbox manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

2.4 Measurements

2.4.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimized shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

2.5 Flexible couplings

2.5.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Chapters 1, 2 and 3.

■ *Section 3* Shaft alignment calculations

3.1 Design calculations

3.1.1 The shaft alignment calculations required by 2.1.2 and 2.1.3 are to be in accordance with the requirements of 3.1.2 to 3.1.5.

3.1.2 For the purpose of the calculations, the following assumptions are to be made:
(a) The shafting base line, to which all slopes and deflections are to be referred, is to be taken as the nominal centreline of the shafting as shown on the shafting arrangement plan. This is to be established as the line of sight on the vessel.
(b) The centreline of the shaft at the mid-length of the bearing adjacent to the propeller lies on the nominal centreline of the shafting.
(c) The centreline of the shaft at the mid-length of each of the other bearings lies initially on the nominal centreline of the shafting.
(d) The propeller and shaft masses act at right angles to the nominal centreline.
(e) The propeller and shaft weights are reduced due to immersion in water and oil as applicable.
(f) The load distribution in the outboard bearings and sterntube bearings is not uniform along the bearing length.
(g) The load on each plummer and bulkhead bearing is concentrated at the mid-length of the bearing.

3.1.3 The bearing loads corresponding with the shaft centreline at each bearing lying on the nominal centreline of the shafting are to be calculated together with a set of influence coefficients for each bearing. The set of influence coefficients for one bearing is to show for a downwards vertical displacement at that bearing of 0,25 mm, the change in load upon it and upon each of the other bearings.

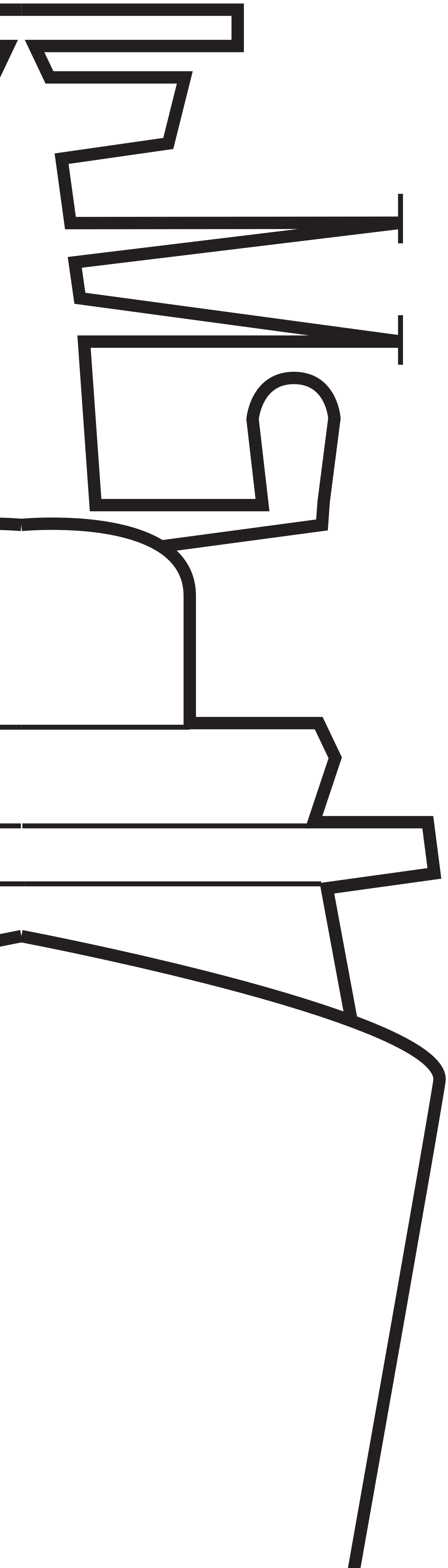
3.1.4 If the distribution of the bearing loads corresponding with the shaft centreline at each bearing lying on the nominal centreline of the shafting is not acceptable, a satisfactory distribution of load is to be obtained by introducing vertical offsets of the bearings upwards or downwards as necessary.

3.1.5 In some arrangements, the disposition of the main gearbox relative to the nearest plummer block may result in an excessive bending stress in the shaft unless the main gearwheel shaft bearings are assumed to carry the weight of the part of the intervening shafting in addition to the weight of the gearwheel and its shaft. In such arrangements, offsets for the main wheel bearings are to be selected to provide a distribution of load on the main gearwheel forward and aft bearings acceptable to the gearing designer.

3.1.6 Using the selected bearing offsets, the bending moment and deflection diagrams are to be drawn and the slopes through the sterntube and bracket bearings relative to a defined datum established both for as new and for maximum weardown of outboard bearings.

3.1.7 To ensure that the shafting system will be supported at the slope and heights calculated, allowance is to be made for:

(a) Bearing clearances.
(b) Compression of bearing materials under load.
(c) Expansion of bearing material due to immersion in water.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 6*

Steering systems

January 2005

Lloyd's Register

Chapter Contents

Volume 2, Part 6

Contents

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering gear and is to be read in conjunction with the requirements for Machinery and Engineering Systems in Pt 1, Ch 1 and Ch 2.

1.1.2 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

1.1.3 Attention is to be given to any relevant requirements of the Naval Authority.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudderstock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.2.3 **Steering gear power unit** means:
(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) in the case of electro-hydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which converts directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with 4.1.2(b).

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:
(a) readily accessible and, as far as practicable, separated from machinery spaces; and
(b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings and scantlings.

2.2.2 Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.

2.2.3 Details of control and electrical aspects.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the ship has been designed.

2.3.2 Where the Naval Authority defines rudder roll stabilisation requirements, details of the system are to be submitted. The control engineering systems are to be in accordance with Pt 9, Ch 1.

2.3.3 Material specifications.

2.3.4 A Failure Mode and Effects Analysis (FMEA) as required by Pt 1, Ch 2 is to be submitted. The FMEA is to address the steering system and is to include the following associated sub-systems:

Hydraulic.
Securing/mounting.
Control and monitoring.
Electrical power supplies.

It is not necessary to consider failure modes relating to the steering gear components.

2.3.5 Noise and vibration acceptance levels for the steering equipment and compartment defined by the Naval Authority where applicable.

■ *Section 3* Materials

3.1 General

3.1.1 All the steering gear components are to be of sound reliable construction to the Surveyor's satisfaction.

3.1.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of Vol 2, Pt 2.

3.1.3 Ram cylinders; pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of Vol 2, Pt 2. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

3.1.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

■ *Section 4* Performance

4.1 General

4.1.1 Unless the main steering gear comprises two or more identical power units, in accordance with 4.1.4, every ship is to be provided with a main steering gear and an auxiliary steering gear in accordance with the requirements of the Rules. The main steering gear and the auxiliary steering gear is to be so arranged that the failure of one of them will not render the other one inoperative.

4.1.2 The main steering gear and rudder stock is to be:

(a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in accordance with Pt 1, Ch 2,15.4.2;
(b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds;
(c) operated by power where necessary to meet the requirements of (b) and in any case when the Rules excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and
(d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

4.1.3 The auxiliary steering gear is to be:

(a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;
(b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
(c) operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

4.1.4 Where the main steering gear comprises two or more identical power units, an auxiliary steering gear need not be fitted, provided that, the main steering gear is capable of operating the rudder as required by 4.1.2(b) while any one of the power units is out of operation.

4.1.5 Main and auxiliary steering gear power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure.
(b) Capable of being brought into operation from each steering position. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given at each steering position.
(c) Arranged so that transfer between units can be readily effected.

4.1.6 Where the steering gear is so arranged that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

4.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

4.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

4.1.9 Manually operated gears are only acceptable when the operation does not require an effort exceeding 16 kg under normal conditions.

4.2 Rudder angle limiters

4.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronized with the gear itself and not with the steering gear control.

■ *Section 5* Design and construction

5.1 General

5.1.1 Rudder actuators are to be designed in accordance with the relevant requirements of Pt 8, Ch 2 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

5.1.2 Accumulators, if fitted, are to comply with the relevant requirements of Pt 8, Ch 2.

5.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

5.1.4 The construction is to be such as to minimize local concentrations of stress.

5.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in 4.1.2(b) taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

5.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values:

$$= \frac{\sigma_B}{A} \quad \text{or} \quad \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

5.2 Rudder, rudder stock, tiller and quadrant

5.2.1 For the requirements of rudder and rudder stock, *see* Vol 1, Pt 3, Ch 3,2.

5.2.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see* Table 1.5.1.

5.2.3 The factor of safety against slippage, *S* (i.e. for torque transmission by friction) is generally based on

$$S = \frac{\text{the torque transmissible by friction}}{M}$$

where *M* is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

5.2.4 For conical sections, *S* is based on the following equation:

$$S = \frac{\mu\, A\, \sigma_r}{\sqrt{(W + A\, \sigma_r\, \tau)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\dfrac{2M}{d_m}$ in N

where d_m in mm is the mean contact diameter of tiller/stock interface and *M,* in Nmm is defined in 1.6.3

θ = cone taper half angle in radians (e.g. for cone taper 1:10, θ = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

Table 1.5.1 Connection of tiller to stock (*see continuation*)

Item	Requirements
(1) Dry fit – tiller to stock (*see also* 5.2.3 and 5.2.4)	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit - tiller to stock (*see also* 5.2.3 and 5.2.4)	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤ 1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2
(4) Bolted tiller and quadrant (this arrangement could be accepted provided the proposed rudder stock diameter in way of tiller does not exceed 350 mm diameter) (*see* symbols)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\,\delta_{su}$ mm For 6 connecting bolts: $t_s = 0{,}0012\,\delta_{su}$ mm Key(s) to be fitted Diameter of bolts, $\delta_T = \dfrac{0{,}60\delta_{su}}{\sqrt{n_T}}$ mm A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted. Distance from centre of stock to centre of bolts should generally be equal to $\delta_{su}\left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_T}}\right)$ Thickness of flange on each half of the bolted tiller $\geq \dfrac{0{,}30}{n_T}$ mm
(5) Key/keyway (*see* symbols)	Effective sectional area of key in shear ≥ $0{,}25\,\delta_{su}{}^2$ mm^2 Key thickness ≤ $0{,}17\,\delta_{su}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* symbols)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15\,\delta_{su}{}^3\,(b_T - b_s)}{1000\,b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06\,\delta_{su}{}^3\,(b_T - 0{,}9\,\delta_{su})}{1000\,b_T}$ cm^3 If more than one arm fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2
(7) Boss (*see* symbols)	Depth of boss ≥ δ_{su} Thickness of boss in way of tiller ≥ $0{,}4\delta_{su}$

Table 1.5.1 Connection of tiller to stock (*conclusion*)

Symbols	
b_S = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm NOTE: b_T and b_S are to be measured with zero rudder angle b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm n_T = number of bolts in the connection flanges, but generally not to be taken greater than six	t_S = thickness of shim for machining bolted tillers and quadrants, in mm Z_{TA} = section modulus of tiller arm, in cm^3 δ_{su} = Rule rudderstock diameter in way of tiller (*see* Vol 1, Pt 3, Ch 3) δ_T = diameter of bolts securing bolted tillers and quadrants, in mm

5.3 Components

5.3.1 Special consideration is to be given to the suitability of any essential component which is not duplicated. Any such essential component shall, where appropriate, utilize anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

5.3.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

5.3.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

5.3.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

5.3.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Pt 7, Ch 1 for Class I piping systems components. The design pressure is to be in accordance with 5.1.5.

5.3.6 Hydraulic power operated steering gear are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system.

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank is to be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

5.4 Valve and relief valve arrangements

5.4.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.4.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.4.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.4.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 5.4.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.

(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them). Under such conditions the rise in pressure. is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.5 Flexible hoses

5.5.1 Hose assemblies approved by Lloyd's Register (hereinafter referred to as 'LR') may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery. (*See also* Pt 7, Ch 1,13).

5.5.2 Hoses should be high pressure hydraulic hoses according to recognized standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

5.5.3 Burst pressure of hoses is to be not less than four times the design pressure.

5.6 Noise and vibration

5.6.1 The reduction of airborne noise, and the structural vibration caused by the steering equipment, is to be regarded as an essential part of the design. The noise and vibration acceptance levels are normally to be defined by the Naval Authority for each ship. The techniques to be employed to achieve this are:

(a) Reduction of noise and vibration at source.

(b) Control of noise and vibration transmission paths by use of vibration mounting systems, structural damping, hydraulic silencers and flexible pipes.

5.6.2 All possible noise and vibration transmission paths are to be considered to eliminate noise shorts.

■ *Section 6* Steering control systems

6.1 General

6.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment.

(b) Where the main steering gear is arranged according to 4.1.4, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.

(c) For the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear.

(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

6.1.2 Any main and auxiliary steering gear control system operable from the navigating bridge is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.

(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

6.1.3 The angular position of the rudder shall:

(a) If the main steering gear is power operated, be indicated at all conning positions. The rudder angle indication is to be independent of the steering gear control system.

(b) Be recognizable in the steering gear compartment.

6.1.4 Appropriate operating instructions with a block diagram showing the change-over procedures for steering gear control systems and steering gear actuating systems are to be permanently displayed in the wheel-house and in the steering gear compartment.

6.1.5 Where the system failure alarms for hydraulic lock (*see* Table 1.8.1) are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

■ *Section 7* Electrical power circuits and equipment

7.1 Electric power circuits, electric control circuits, monitoring and alarms

7.1.1 Short circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

7.1.2 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

7.1.3 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors.

7.1.4 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

7.1.5 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

7.1.6 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

7.1.7 These circuits are to be separated throughout their length as widely as is practicable.

7.1.8 Where agreed by the Naval Authority, in ships of category NS3, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements than described in 7.1.1, for such a motor primarily intended for other services.

7.2 Electric control circuits

7.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

7.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:
(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected.
(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 8* Monitoring and alarms

8.1 Monitoring

8.1.1 Alarms and monitoring requirements are indicated in 8.1.2, 8.1.3 and Table 1.8.1.

8.1.2 The angular position of the steering mechanism is to:
(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.
(b) Be recognizable in the steering unit compartment, if applicable.

8.1.3 The alarms described in Table 1.8.1 are to be indicated on the navigating bridge and in accordance with the alarm system specified by Pt 9, Ch 1.

Table 1.8.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	–	Indication, *see* 8.1.2
Steering power units, power	Failure	—
Steering motors	Overload single phase	Also running indication on bridge and machinery control station, *see* 7.1.2
Control system power	Failure	—
Steering gear hydraulic oil tank level	Low	Each tank to be monitored
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each each system is to be monitored (*see* Note)
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and to be activated when (for example):
Position of the variable displacement pump control system does not correspond with given order; or incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

■ *Section 9* Alternative sources of power and emergency operation

9.1 Alternative sources of power

9.1.1 An alternative power supply sufficient to supply the steering gear power unit that complies with the requirements of 4.1.2 and also its associated control systems and rudder angle indicator, is to be provided automatically, within 45 seconds of loss of the main power supply, either from an emergency or alternative source of electrical power complying with Pt 10, Ch 1,3 or from an independent source of power located in the steering gear compartment. Where an independent source of electrical power located in the steering gear compartment is used as an alternative power supply, this source is to be used only for this purpose.

9.1.2 The alternative power supply shall have a capacity for at least 30 minutes of continuous operation. A greater or lesser period of time may be considered in conjunction with the operational requirements of the Naval Authority and any assigned Service Restriction.

9.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

9.2 Emergency hand pump operation

9.2.1 Hydraulically operated steering gears are to be provided with an emergency hand pump permanently fitted in a readily accessible position in the steering gear compartment. The pump is to be permanently connected between the reservoir and the main hydraulic system.

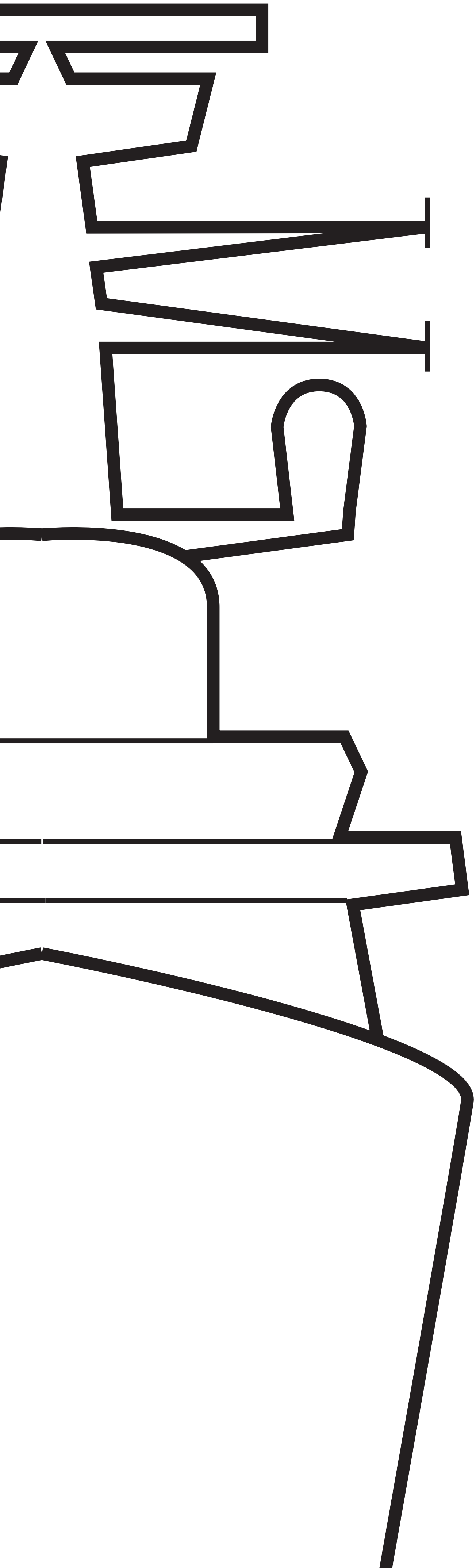
9.2.2 The hand pump is to be capable of moving the rudder to mid-position in the absence of electrical power, and being operated by not more than two men. It is to be capable of moving the rudder(s) up to 10° either side at ship speeds up to 10 knots, and 5° at ship speeds above 10 knots.

9.3 Emergency capability

9.3.1 For use in an emergency condition, facilities are to be provided to hydraulically lock the rudder actuators in the mid-position when the pumps are stopped. Isolating valves are to be fitted direct onto the rudder actuators.

9.3.2 An independent means of mechanically restraining the rudder amidships is to be provided.

9.3.3 Where there is more than one rudder fitted, arrangements are to be such that any rudder can be hydraulically and mechanically locked whilst allowing use of the other rudder(s).



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 7*

Piping systems

January 2005

Lloyd's Register

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■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to all naval ships intended to be classed and covers the design and construction of essential piping systems, including components and fittings forming part of such systems.

1.1.2 The provisions of this Chapter do not address pipe size selection in respect of adequacy to satisfy design requirements for flow rates and/or heat transfer in piping systems.

1.1.3 The Sections detail information necessary for verifying the adequacy of design in respect of strength and suitability for intended purpose with regard to materials and scantlings.

1.1.4 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

■ *Section 2* General

2.1 Documentation

2.1.1 Documents indicating the following information are to be submitted for each piping system in triplicate:

Design pressure.
Design temperature.
Class of system.
Internal pipe diameter and thickness.
Material specification.
Corrosion protection.
Corrosion allowance.
Pipe connection specifications.
Valve specifications.
Flexible hose specifications.
Expansion piece specifications.
Details of any other pipe fittings.
Pumping unit type and discharge characteristics.
Testing procedures.

2.1.2 Where the Owner/Operator has specified requirements for the life of a particular piping system under defined operating conditions, details of enhanced pipe scantlings and assumptions made are to be submitted for review.

2.2 Definitions

2.2.1 **Essential piping systems** are those systems installed for the propulsion and safety of the ship within the Mobility category and Ship Type category (*see* Pt 1, Ch 1,3) and include the following:

Air and overflow arrangements.
Sounding arrangements.
Bilge and dewatering systems.
Ballast systems.
Oil fuel systems.
Gas fuel systems.
Lubricating oil systems.
Thermal oil systems.
Hydraulic oil systems for:
- steering gears;
- controllable pitch propellers;
- thrust units for propulsion and/or dynamic positioning;
- windlass machinery;
- watertight bow, stern, side and internal doors;
- valve control systems, etc.

Fresh water cooling systems for machinery.
Sea water cooling systems.
Compressed air systems for starting engines, control and alarms.
Feed water systems.
Steam and condensate systems.
Exhaust and flue gas systems.
Control systems for remote operation of valves and ventilation flaps.

2.2.2 **Non-essential piping systems** are those systems installed for conditions of habitability and recreation, are within the Ancillary category and include the following:
Heating systems.
Air conditioning systems.
Domestic sanitary and fresh water systems.

2.2.3 **Piping system** includes pipes and fittings such as expansion joints, valves, pipe joints, support arrangements, flexible tube lengths etc., and components in direct connection with the piping such as pumps, heat exchangers, air receivers, independent tanks, etc. It does not include main and auxiliary machinery such as oil engines, steam and gas turbines, boilers, reduction gears, etc.

2.3 Classes of piping systems and components

2.3.1 For the purpose of testing, the type of joint to be adopted, heat treatment and welding procedure, pipes are subdivided into three classes as indicated in Table 1.2.1.

Table 1.2.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II p	Class II T	Class III p	Class III T
	bar	deg C	bar	deg C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable liquids (see Note)	16,0	150	7,0	60
Other media	40,0	300	16,0	200

NOTES
1. Flammable liquids include; oil fuel; lubricating oil and flammable hydraulic oil.
2. For grey cast iron, *see also* 8.2.2.

2.3.2 Dependent on the service for which they are intended, Class II and Class III piping are not to be used for design pressure or temperature conditions in excess of those shown in Table 1.2.1. Where either the maximum design pressure or temperature exceeds that applicable to Class II piping systems, Class I piping is to be used.

2.3.3 In addition to the pressure piping systems in Table 1.2.1 Class III pipes may be used for open ended piping, e.g. overflows, vents, open ended drains, etc.

Section 3
Assessment

3.1 Design and construction

3.1.1 All piping systems are to be designed and constructed for their intended service and working conditions.

3.1.2 Materials sensitive to heat, such as aluminium and plastics, are not to be used in essential systems necessary for the safe operation of the ship, or for containing flammable liquids or sea water where leakage or failure could result in fire or in flooding of a watertight compartment.

3.1.3 The strength and construction of pipes, components and fittings is to preclude loss of essential services, escape of flammable liquid and flooding.

3.1.4 The selection of pipe connections in piping systems is to recognise the boundary fluids, pressure and temperature conditions and location.

3.1.5 Pipe connections in accordance with national or other approved standards will be accepted where the standards are appropriate to the piping system.

3.1.6 Pipe thicknesses greater than the minimum required by this Chapter may be necessary where the likelihood of erosion cannot be avoided and/or where there is a likelihood of corrosion exceeding the nominal allowances specified in the Rule requirements. Pipe thicknesses may also need to be increased where the Owner/Operator has specified requirements for system life, *see* 2.1.2.

3.2 Design symbols

3.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
d = inside diameter of pipe, in mm (*see* 3.2.3)
e = weld efficiency factor (*see* 3.2.4)
p = design pressure, in bar (*see* 3.3)
p_t = hydraulic test pressure, in bar
t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
D = outside diameter of pipe, in mm (*see* 3.2.2)
R = radius of curvature of a pipe bend at the centre line of the pipe, in mm
T = design temperature, in °C (*see* 3.4)
σ = maximum permissible design stress, in N/mm^2.

3.2.2 The outside diameter, D, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

3.2.3 The inside diameter, *d*, is not to be confused with nominal size, which is an accepted designation associated with outside diameters of standard rolling sizes.

3.2.4 The weld efficiency factor, *e*, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of *e* will be specially considered.

3.3 Design pressure

3.3.1 The design pressure, *p*, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

3.3.2 In water tube boiler installations, the design pressure for steam piping between the boiler and integral superheater outlet is to be taken as the design pressure of the boiler, i.e. not less than the highest set pressure of any safety valve on the boiler drum. For piping leading from the superheater outlet, the design pressure is to be taken as the highest set pressure of the superheater safety valves.

3.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

3.3.4 For pipes containing heated oil under pressure (temperature 60°C and above and pressure 0,18 bar and above), the design pressure is to be taken as not less than 14 bar.

3.3.5 For design pressure of steering gear components and piping, *see* Pt 6, Ch1.

3.4 Design temperature

3.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

3.4.2 In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15°C above the designed temperature are to be expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

3.5 Use of alternative design codes

3.5.1 Where it is proposed to use a material with a minimum specified tensile strength different from that indicated in Tables 1.6.1, 1.6.2 or 1.7.1 and the material is in accordance with a recognized National/International Standard, the use of alternative design codes for calculating pipe stresses will be accepted. The design code used is to be suitable for the intended application.

3.5.2 Where alternative design codes are used, they are to be stated together with any assumptions made.

■ *Section 4* Materials

4.1 Metallic materials

4.1.1 Materials for Class I and II piping systems and components as defined in Table 1.2.1, also for shell valves and fittings and fittings on the collision bulkhead are to be manufactured and tested in accordance with Vol 1, Part 2.

4.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR').

4.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

4.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in Table 1.4.1.

Table 1.4.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature °C	*DN* = Nominal diameter, mm P_W = Working pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron	< 300	$DN < 50$ or $P_W \times DN < 2500$
Copper alloy	<200	$DN < 50$ or $P_W \times DN < 1500$

4.2 Non-metallic materials

4.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with Vol 1, Pt 2, Ch 14.

■ *Section 5* Pipe connections

5.1 General

5.1.1 Connections in piping systems may be made by any of the methods described in this Section, or by special types of approved joints which have been shown to be suitable for the design conditions. Details of connection methods, not described in this Section are to be submitted for consideration.

5.1.2 The selection of pipe connections in piping systems is to recognise the boundary fluids, pressure and temperature conditions, external or cyclic loading and location.

5.1.3 Pipe connections in accordance with national or other established standards will be accepted where the standards are appropriate to the piping system.

5.1.4 The type and location of pipe connections are to recognise the need to facilitate Periodic Survey of piping systems and associated items of machinery and the need for cold 'pull up' if required.

5.1.5 Pipe connections are not to be used to compensate for pipe misalignment.

5.1.6 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

5.1.7 Pipes passing through, or connected to, watertight decks are to be continuous or provided with an approved bolted or welded connection to the deck or bulkhead.

5.1.8 For details of non-destructive tests on piping systems, other than hydraulic tests, *see* Pt 1, Ch 3.

5.1.9 The requirements in 5.2 to 5.8 are applicable to connections in metallic piping systems.

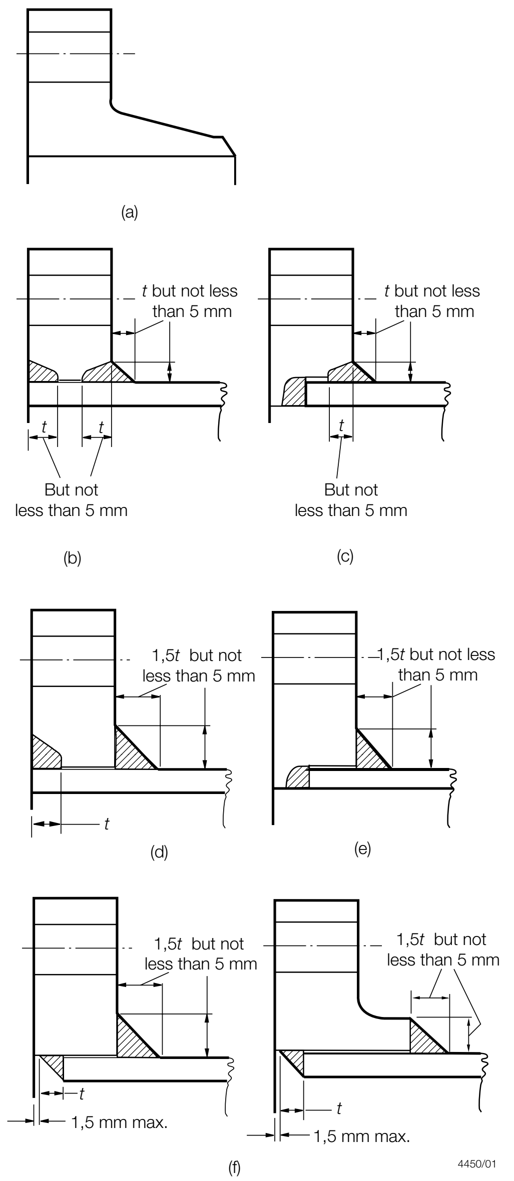


Fig. 1.5.1 Typical welded-on flanges

5.2 Flange connections

5.2.1 The dimensions and configuration of flanges and bolting are to be selected in accordance with recognised standards. The dimensions and bolting arrangements of non-standard flanges will be the subject of special consideration.

5.2.2 Gaskets are to be suitable for the fluids under design pressure and temperature conditions and their dimensions and configuration is to be in accordance with recognised standards. Gasket materials used in oil piping systems are to be impervious to oil and the thinnest possible.

5.2.3 Acceptable flange pipe connections are indicated in Fig. 1.5.1. Limiting applications of different types of flange connections are indicated in Table 1.5.1 depending on the size, pressure and temperature.

5.3 Screwed-on flanges

5.3.1 Where flanges are secured by screwing, as indicated in Fig. 1.5.2, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

5.3.2 The vanishing thread on a pipe is to be not less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

Table 1.5.1 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

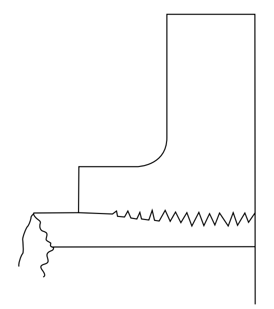


Fig. 1.5.2 Screwed on flange

5.3.3 Such screwed and expanded flanges may be used for steam for a maximum design pressure of 30 bar and a maximum design temperature of 370°C and for feed for a maximum design pressure of 50 bar.

5.4 Welded-on flanges, butt welded joints and fabricated branch pieces

5.4.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

5.4.2 Butt welded joints are generally to be of the full penetration type and are to meet the requirements of Pt 1, Ch 3.

5.4.3 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.4.4 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.4.5 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.4.6 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Pt 1, Ch 3.

5.5 Loose flanges

5.5.1 Loose flange designs as shown in Fig. 1.5.3 may be used provided they are in accordance with a recognised National or International Standard.

5.5.2 Loose flange designs where the pipe end is flared as shown in Fig. 1.5.3(b) are only to be used for water pipes and on open ended lines.

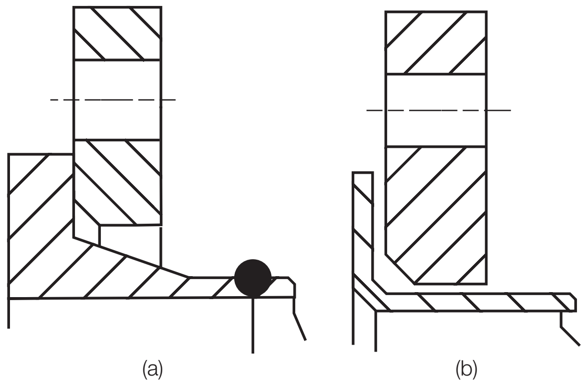


Fig. 1.5.3 Loose flange arrangements

5.6 Socket weld joints

5.6.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket welded joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of 6.1.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7 Threaded sleeve joints

5.7.1 Threaded sleeve joints, in accordance with national or other established standards, may be used with carbon steel pipes within the limits given in Table 1.5.2. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

5.8 Welded sleeve joints

5.8.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

Table 1.5.2 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class 1	Class II	Class III
Tapered thread	<33,7	<60,3	<60,3
Parallel thread	—	—	<60,3

5.8.2 Sleeve joints are not to be used in the following locations:

- Piping for the storage, distribution and utilization of fuel, lubricating or other flammable oil systems in machinery spaces, *see also* Ch 3,4.5.1.
- Bilge pipes in way of deep tanks
- Cargo oil piping outside of the cargo area for bow or stern loading/discharge
- Air and sounding pipes passing through cargo tanks

5.8.3 Welded sleeve joints are not to be used at deck/bulkhead penetrations that require continuous pipe lengths.

5.8.4 The thickness of the sleeve is to satisfy the requirements of 6.1.3 and Table 1.6.4 but is to be not less than the nominal thickness of the pipe. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve.

5.8.5 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.8.6 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0{,}14D + 36 \text{ mm}$$

where

L_{si} is the length of the sleeve
D is defined in 3.2.1.

5.9 Screwed fittings

5.9.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

5.10 Mechanical connections for piping

5.10.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 1.5.4, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table1.5.3 and dependence upon the Class of piping, with limiting pipe dimensions, working pressure and temperature is indicated in Table 1.5.4.

5.10.2 Where the application of mechanical joints results in a reduction of pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

5.10.3 The construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects during operation on board.

5.10.4 The materials used in the construction of mechanical joints are to be compatible with the piping material and internal/external media.

5.10.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.10.6 In general, mechanical joints are to be of fire resistant type where required by Table 1.5.3.

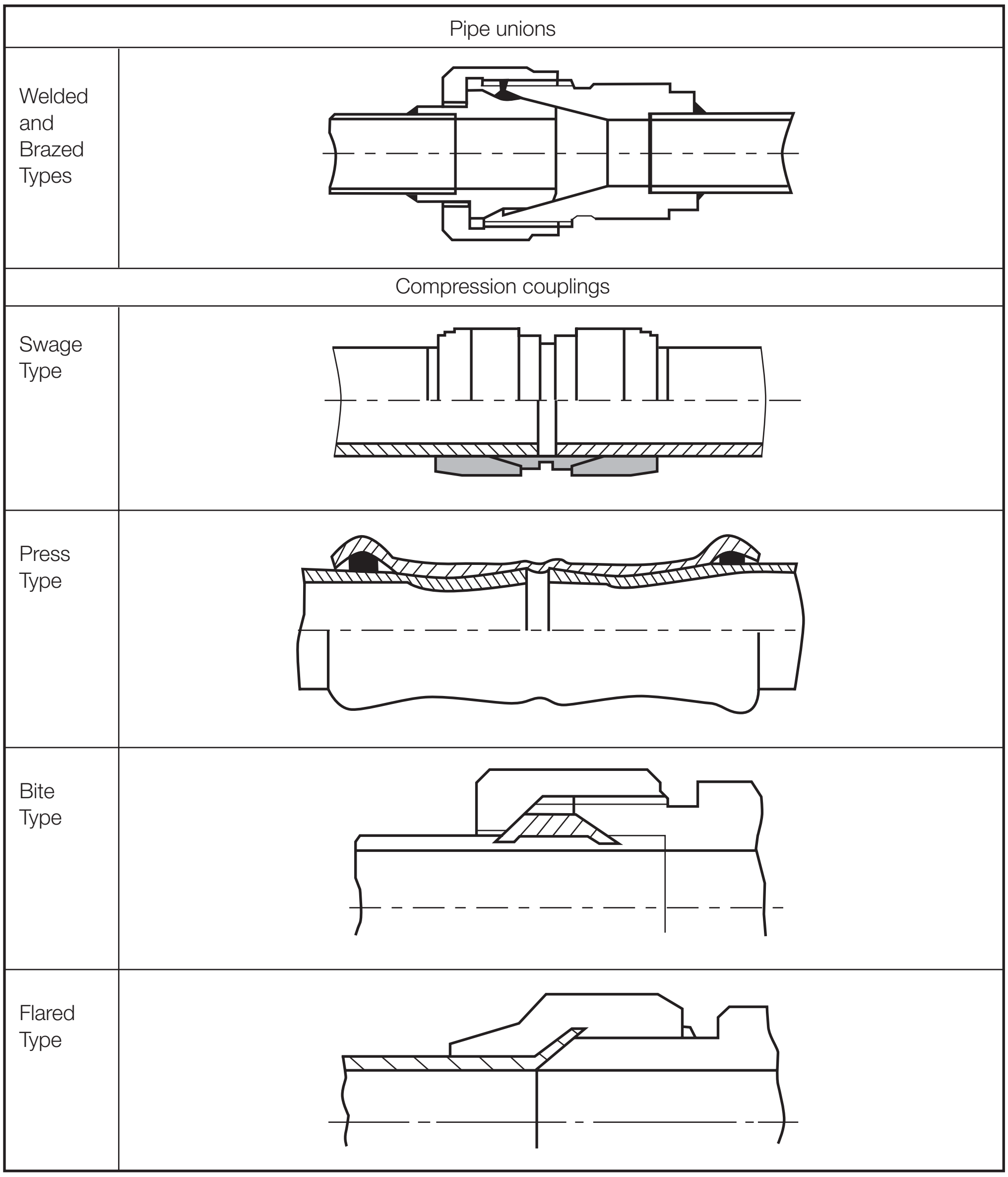


Fig. 1.5.4 Examples of mechanical joints (*continued*)

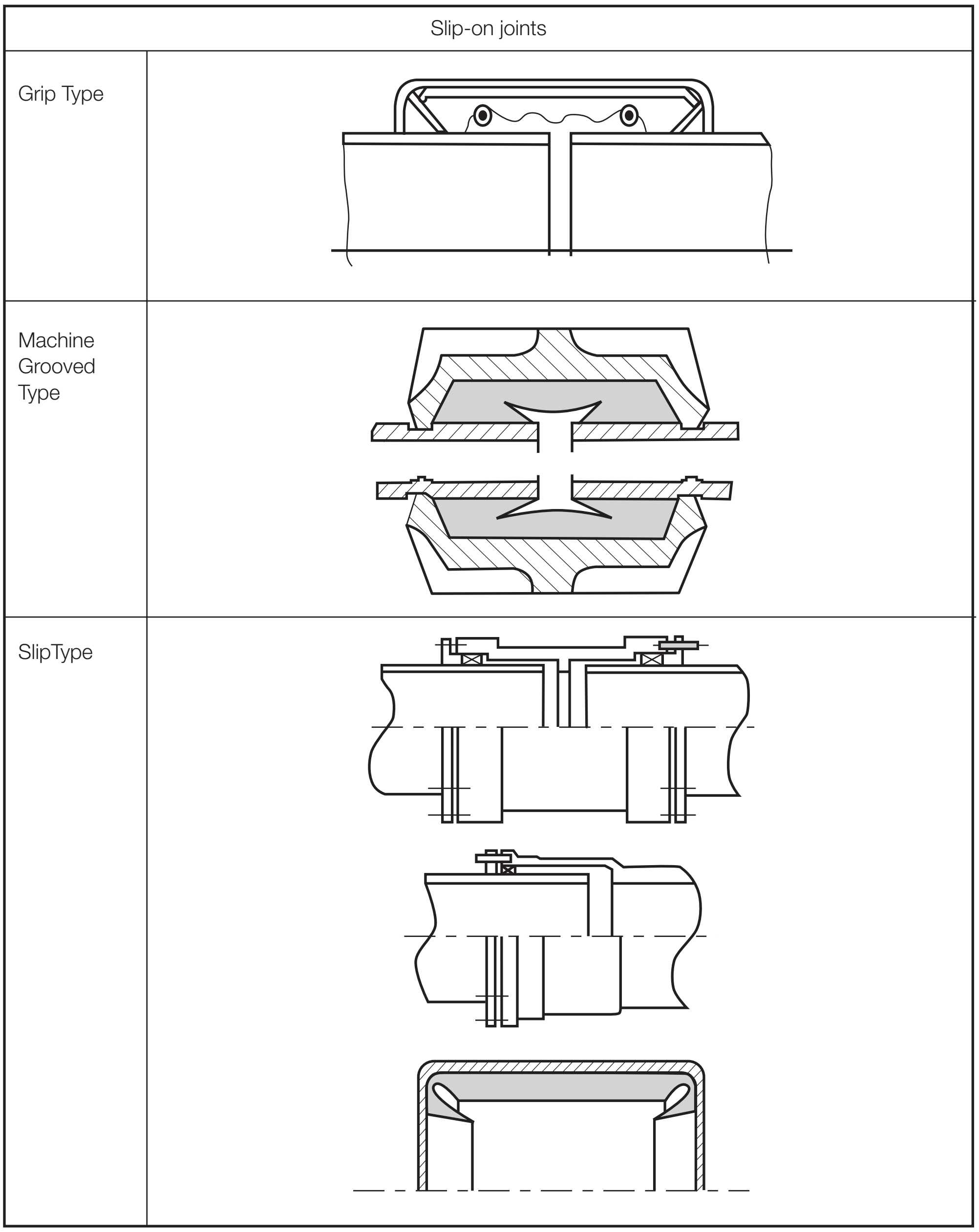


Fig. 1.5.4 Examples of mechanical joints (*conclusion*)

5.10.7 Mechanical pipe connections having sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

5.10.8 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.10.9 The mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.10.10 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

5.10.11 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

5.10.12 Restrained slip-on joints are permitted in steam pipes on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see* Ch 2,2.7.

Table 1.5.3 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression Couplings (6)	Slip-on Joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distributions lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	-
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	—7

KEY
+ Application is allowed
— Application is not allowed

NOTE
1. Inside machinery spaces of category A – only approved fire resistant types.
2. Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.
7. *See* 5.10.12.

Table 1.5.4 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+

KEY
+ Application is allowed
– Application is not allowed

Section 6
Carbon and low alloy steel piping and components

6.1 Wrought steel pipes and bends

6.1.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of the maximum permissible design stress, σ, obtained from the properties of the steels specified in Vol 1, Pt 2, Ch 6 are shown in Tables 1.6.1 and 1.6.2. For intermediate values of specified minimum strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

6.1.2 Where it is proposed to use, for high temperature service, alloy steels other than those detailed in Table 1.6.2 particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

Table 1.6.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible stress, N/mm^2 — Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

Table 1.6.2 Alloy steel pipes

Type of steel	Specified minimum tensile strength, N/mm²	Maximum permissible stress, N/mm²									
		Maximum design temperature, °C									
		50	100	200	300	350	400	440	450	460	470
1 Cr ½ Mo	440	159	150	137	114	106	102	101	101	100	99
2¼ Cr 1 Mo annealed	410	76	67	57	50	47	45	44	43	43	42
2¼ Cr 1 Mo normalised and tempered (Note 1)	490	167	163	153	144	140	136	130	128	127	116
2¼ Cr 1 Mo normalised and tempered (Note 2)	490	167	163	153	144	140	136	130	122	114	105
½ Cr ½ Mo ¼ V	460	166	162	147	120	115	111	106	105	103	102
		Maximum design temperature, °C									
		480	490	500	510	520	530	540	550	560	570
1 Cr ½ Mo	440	98	97	91	76	62	51	42	34	27	22
2¼ Cr 1 Mo annealed	410	42	42	41	41	41	40	40	40	37	32
2¼ Cr 1 Mo normalised and tempered (Note 1)	490	106	96	86	76	67	58	49	43	37	32
2¼ Cr 1 Mo normalised and tempered (Note 2)	490	96	88	79	72	64	56	49	43	37	32
½ Cr ½ Mo ¼ V	460	101	99	97	94	82	72	62	53	45	37

NOTES
1. Maximum permissible stress values applicable when the tempering temperature does not exceed 750°C.
2. Maximum permissible stress values applicable when the tempering temperature exceeds 750°C.

6.1.3 The minimum thickness, *t*, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma e + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where *p*, *D*, *e* and *a* are as defined in 3.2.1

c is obtained from Table 1.6.3

σ is defined in 2.2.1 and obtained from Table 1.6.1 or Table 1.6.2

For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 1.6.4. Where the pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

Table 1.6.3 Values of *c* for steel pipes

Piping service	*c* mm
Superheated steam systems	0,3
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Oil fuel systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

Table 1.6.4 Minimum thickness for steel pipes

External diameter *D* in mm	Pipes in general in mm	Venting, overflow and sounding pipes for structural tanks in mm	Bilge, ballast and general sea-water pipes in mm	Bilge, air, overflow and sounding pipes through ballast and fuel tanks, ballast lines through fuel tanks and fuel lines through ballast tanks in mm
10,2–12	1,6	–	–	–
13,5–19	1,8	–	–	–
20	2,0	–	–	–
21,3–25	2,0	–	3,2	–
26,9–33,7	2,0	–	3,2	–
38–44,5	2,0	4,5	3,6	6,3
48,3	2,3	4,5	3,6	6,3
51–63,5	2,3	4,5	4,0	6,3
70	2,6	4,5	4,0	6,3
76,1–82,5	2,6	4,5	4,5	6,3
88,9–108	2,9	4,5	4,5	7,1
114,3–127	3,2	4,5	4,5	8,0
133–139,7	3,6	4,5	4,5	8,0
152,4–168,3	4,0	4,5	4,5	8,8
177,8	4,5	5,0	5,0	8,8
193,7	4,5	5,4	5,4	8,8
219,1	4,5	5,9	5,9	8,8
244,5–273	5,0	6,3	6,3	8,8
298,5–368	5,6	6,3	6,3	8,8
406,4–457,2	6,3	6,3	6,3	8,8

NOTE
The pipe diameters and wall thicknesses given in the table are based on common international standards. Diameter and thickness according to other National or International Standards will be considered.

6.1.4 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than tb would not reduce the thickness below *t* at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma e + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where *p*, *D*, *R*, *e* and *a* are as defined in 3.2.1
σ and *c* are as defined in 6.1.3. In general, *R* is to be not less than 3*D*.

6.1.5 Where the minimum thickness calculated by 6.1.3 or 6.1.4 is less than that shown in Table 1.6.4, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance, or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be specially considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

6.1.6 For air, bilge, ballast, fuel, overflow, sounding and venting pipes as listed in Table 1.6.4, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.

6.1.7 The internal diameter for bilge, venting and overflow pipes listed in Table 1.6.4 is to be not less than 50 mm. The internal diameter for sounding pipes is to be not less than 32 mm.

■ *Section 7* Copper and copper alloy piping and components

7.1 Copper and copper alloy pipes, valves and fittings

7.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Vol 1, Pt 2, Ch 9, *see also* 4.1.

7.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material.

7.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

7.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyors.

Table 1.7.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2 — Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	–	–	–	–
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	–	–	–	–
90/10 Copper-nickel-iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

7.1.5 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Vol 1, Pt 2, Ch 9 may be accepted up to 260°C.

7.1.6 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where p, D and a are as defined in 3.2.1

c = corrosion allowance
= 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media are non-corrosive relative to the pipe material

σ = maximum permissible design stress, in N/mm^2, from Table 1.7.1. Intermediate values of stresses may be obtained by linear interpolation.

7.1.7 The minimum thickness, t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than tb would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where p, D, R and a are as defined in 3.2.1
σ and c are as defined in 7.1.6. In general, R is to be not less than $3D$.

7.1.8 Where the minimum thickness calculated by 7.1.6 or 7.1.7 is less than shown in Table 1.7.2, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

Table 1.7.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter) mm		mm	Minimum overriding nominal thickness — Copper mm	Copper alloy mm
8	to	10	1,0	0,8
12	to	20	1,2	1,0
25	to	44,5	1,5	1,2
50	to	76,1	2,0	1,5
88,9	to	108	2,5	2,0
133	to	159	3,0	2,5
193,7	to	267	3,5	3,0
273	to	457,2	4,0	3,5
		508	4,5	4,0

7.2 Heat treatment

7.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 8*
Cast iron piping and components

8.1 Spheroidal or nodular graphite cast iron

8.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

8.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of , where $5{,}65\sqrt{S_o}$ is the actual cross-sectional area of the test piece.

8.1.3 Castings for Class II systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of Vol 1, Pt 2, Ch 7. Castings for Class III systems are to comply with the requirements of acceptable national specifications. A manufacturer's test certificate will be accepted and is to be provided for each consignment of material for Class III systems, *see also* 4.1.

8.1.4 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

8.1.5 Where the elongation is less than the minimum required by 8.1.1, the material is, in general, to be subject to the same limitations as grey cast iron.

8.2 Grey cast iron

8.2.1 Grey cast iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in 8.2.3.

8.2.2 Grey cast iron is not to be used for pipes, valves and other fittings handling media having temperatures above 220°C or for piping subject to pressure shock, excessive strains or vibrations.

8.2.3 Grey cast iron is not to be used for the following:

- Pipes for steam systems and fire extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Ship-side valves and fittings, *see* Pt 7, Ch 2,2.5.
- Valves fitted on the collision bulkhead, *see* Pt 7, Ch 2,3.3.
- Bilge lines in tanks.
- Pipes and fittings in flammable oil systems where the design pressure exceeds 7 bar or the design operating temperature is greater than 60°C.
- Valves fitted to tanks containing flammable oil under static pressure.

8.2.4 Castings for Class III piping systems are to comply with acceptable national specifications.

■ *Section 9* Stainless steel piping and components

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of Austenitic steels in sea water systems, *see* 17.3.4.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 6.1.3 or 6.1.4 using a corrosion allowance of 0,8 mm. Values of the 0,2 per cent proof stress and tensile strength of the material for use in the formula in 6.1.1 may be obtained from Table 6.5.2 of Vol 1, Part 2.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0,3 mm.

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in Table 1.9.1.

Table 1.9.1 Minimum thickness for stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
8,0	to	10,0	0,8
12,0	to	20,0	1,0
25,0	to	44,5	1,2
50,0	to	76,1	1,5
88,9	to	108,0	2,0
133,0	to	159,0	2,5
193,7	to	267,0	3,0
273,0	to	457,2	3,5

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in 5.2 to 5.8.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

■ *Section 10* Aluminium piping and components

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In ships of aluminium construction, aluminium alloy may also be used for air and sounding pipes for oil fuel, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying oil fuel, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in Table 1.10.1.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

■ *Section 11* Plastic piping and components

11.1 General

11.1.1 Proposals to use plastics pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

11.1.2 Attention is also to be given to the *Guidelines for the Application of Plastic Pipes on Ships* contained in IMO Resolution A.753(18).

11.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastics in Class I and Class II piping systems will be specially considered.

11.1.4 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

11.1.5 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 11.4, are to be considered.

11.1.6 The use of plastics piping and components for magazine piping systems or for piping systems that may pass through magazine spaces is not permitted.

11.1.7 The use of plastics pipes may be restricted by the Naval Authority.

11.1.8 Where it is proposed to use plastics materials for piping systems and associated equipment installed in naval ships, the Naval Authority may require a risk assessment to be submitted that addresses the following:
(a) the potential fire risks in the space containing the plastics materials;
(b) The effect of a fire in the compartment containing plastics materials in terms of fire spread and of producing excessive quantities of smoke and toxic products.
(c) An engineering justification for the use of plastics materials in preference to metallic materials which are not sensitive to heat.

11.2 Design and performance criteria

11.2.1 Pipes and fittings are to be of robust construction and are to comply with a National or other established Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

11.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 11.3.

11.2.3 Depending on the service and location, the fire safety aspects relating to the use of plastics materials for pipes are to satisfy the requirements of 11.4. *See also* 11.1.8.

11.2.4 Plastics piping is to be electrically conductive when:
(a) carrying fluids capable of generating electrostatic charges;
(b) passing through dangerous zones and spaces, regardless of the fluid being conveyed.
Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 11.5, *see also* Pt 10, Ch 1,1.12.

11.3 Design strength

11.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

11.3.2 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \le \frac{p_{st}}{4}$$

$$pN_i \le \frac{p_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Testing may be carried out over a reduced period of time using suitable standards, such as ASTM D2837 and D1598.

11.3.3 The nominal external pressure, pN_e, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \le \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in bar

The pipe collapse pressure is not to be less than 3 bar.

11.3.4 Piping is to meet these design requirements over the range of service temperature it will experience.

11.3.5 High temperature limits and pressure reductions relative to nominal pressures are to be according to a recognized standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C. *See also* Vol 1, Pt 2, Ch 14,4.

11.3.6 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

11.3.7 For guidance, typical temperature and pressure limits are indicated in Table 1.11.1 and Table 1.11.2. The Tables are related to water service only. Transport of chemicals or other media are to be considered on a case by case basis.

Table 1.11.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar		
		–20 to 0ºC	30ºC	40ºC
HDPE	10	7,5	6	
	16	12	9,5	6
HDPE High density polyethylene				

11.3.8 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

11.3.9 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

11.4 Fire performance criteria

11.4.1 Where plastics pipes are used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested in accordance with the requirements of Table 1.11.3.

11.4.2 The materials used for plastics pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics

11.4.3 The materials used for plastics pipes within accommodation, service and control spaces are not to be capable of producing excessive quantities of smoke and toxic products that may be a hazard to personnel within those spaces.

Table 1.11.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes

Minimum heat distortion temperature of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50 to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

Table 1.11.3 Fire endurance requirements (*see continuation*)

Piping systems	Location: A Machinery spaces of Category A	B Other Machinery spaces	C Special category spaces	D Other dry compartments	E Refuelling tanks (f.p. ≤ 60°C)	F Fuel oil tanks	G Ballast water tanks	H Cofferdams void spaces pipe tunnel and ducts	I Accommodation service and control spaces	J Open decks
FLAMMABLE LIQUIDS (f.p. ≤ 60°C)										
1 Refuelling lines	N/A	N/A	N/A	N/A	0	N/A	0	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. > 60°C)										
2 Refuelling lines	X	X	X	X	N/A[3]	0	0[10]	0	N/A	L1
3 Fuel oil	X	X	X	X	N/A[3]	0	0	0	L1	L1
4 Lubricating oil	X	X	X	X	N/A	N/A	N/A	0	L1	L1
5 Hydraulic oil	X	X	X	X	0	0	0	0	L1	L1
SEAWATER[1]										
6 Bilge main and branches	X	X	X	X	N/A	0	0	0	N/A	L1
7 Fire main and water spray	L1	L1	X	N/A	N/A	N/A	0	0	X	L18
8 Foam system	L1	L1	N/A	N/A	N/A	N/A	N/A	0	L1	L1
9 Sprinkler system	L1	L1	X	N/A	N/A	N/A	0	0	L3	L3
10 Ballast	L3	L3	L3	X	0[10]	0	0	0	L2	L2
11 Cooling water, essential services	L3	L3	N/A	N/A	N/A	N/A	0	0	N/A	L2
12 Non-essential systems	0	0	0	0	N/A	0	0	0	0	0

Table 1.11.3 Fire endurance requirements *(continued)*

Piping systems	Location									
	A Machinery spaces of Category A	B Other Machinery spaces	C Special category spaces	D Other dry compartment	E Refuelling tanks f.p. ≤ 60°C	F Fuel oil tanks	G Ballast water tanks	H Cofferdams void spaces pipe tunnel and ducts	I Accommodation service and control spaces	J Open decks
FRESHWATER 13 Cooling water essential services	L3	L3	N/A	N/A	N/A	0	0	0	L3	L3
14 Condensate return	L3	L3	0	0	N/A	N/A	N/A	0	0	0
15 Non-essential systems	0	0	0	0	N/A	0	0	0	0	0
SANITARY/DRAINS/ SCUPPERS 16 Deck drains (internal)	L1[4]	L1[4]	L1[4]	0	N/A	0	0	0	0	0
17 Sanitary drains (internal)	0	0	0	0	N/A	0	0	0	0	0
18 Scuppers and discharges (overboard)	0[1,6]	0[1,6]	0[1,6]	0[1,6]	0	0	0	0	0[1,6]	0
SOUNDING/AIR 19 Water tanks/dry spaces	0	0	0	0	0	0	0	0	0	0[8]
20 Oil tanks (f.p. > 60°C)	X	X	X	X	X[3]	0	0	0	X	X
MISCELLANEOUS 21 Control air	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L1[5]	L1[5]
22 Service air (non-essential)	0	0	0	0	N/A	0	0	0	0	0
23 Brine	0	0	0	0	N/A	N/A	N/A	0	0	0
24 Auxiliary low pressure steam (≤ 7 bar)	L2	L2	0[7]	0[7]	0	0	0	0	0[7]	0[7]

Table 1.11.3 Fire endurance requirements (*continued*)

LOCATION DEFINITIONS

	Location	Definition
A	Machinery spaces of Category A	Machinery spaces of Category A as defined in Pt 1, Ch 2,5.1.
B	Other machinery spaces	Spaces, other than Category A machinery spaces containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
C	Special category spaces	Spaces and special category spaces as defined in Pt 10, Ch 1,1.5.9.
D	Other dry compartments	All spaces other than special category spaces used for stores and equipment and trunks to such spaces.
E	f.p. ≤ 60ÞC tanks	All spaces used for refuelling fuel and trunks to such spaces.
F	Fuel oil tanks	All spaces used for fuel oil and trunks to such spaces.
G	Ballast water tanks	All spaces used for ballast water and trunks to such spaces.
H	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments.
I	Accommodation, service	Accommodation spaces, service spaces and control stations.
J	Open decks	Open deck spaces.

ABBREVIATIONS

L1	Fire endurance test in dry conditions, 60 minutes. IMO Resolution A.753(18) Appendix 1
L2	Fire endurance test in dry conditions, 30 minutes. IMO Resolution A.753(18) Appendix 1
L3	Fire endurance test in wet conditions, 30 minutes. IMO Resolution A.753(18) Appendix 2
0	No fire endurance test required.
N/A	Not applicable.
X	Metallic materials having a melting point greater than 925°C.

NOTES

1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).
2. Remote closing valves to be provided at the refuelling tanks.
3. When refuelling tanks contain flammable liquids with f.p. > 60°C, '0' may replace 'N/A' or 'X'.
4. For drains serving only the space concerned, '0' may replace 'L1'.
5. When controlling functions are not required by the rules or Naval requirements, '0' may replace 'L1'.
6. Scuppers serving open decks should be 'X' throughout unless fitted at the upper end with the means of closing capable of being operated from a position above the weather deck in order to prevent downflooding.
7. For essential services, such as fuel oil tank heating and ship's whistle, 'X' is to replace '0'.
8. Air and sounding pipes on open deck are to be of substantial construction, *see* Vol 2, Pt 7, Ch 2,10.1.2.

11.4.4 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

11.5 Electrical conductivity

11.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m. (*See also* 11.2.4).

11.5.2 Electrical continuity is to be maintained across the joints and fittings and the system is to be earthed. *See also* Pt 10, Ch 1,1.12. The resistance to earth from any point in the piping system is not to exceed 1 MΩ.

11.6 Manufacture and quality control

11.6.1 All materials for plastics pipes and fittings are to be approved by LR, and are in general to be tested in accordance with Vol 1, Pt 2, Ch 14,4.

11.6.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

11.6.3 Plastics pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

11.6.4 Plastics pipes are to be manufactured and tested in accordance with Vol 1, Pt 2, Ch 14,4. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

11.7 Installation and construction

11.7.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

11.7.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding and laminating.

11.7.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

11.7.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

11.7.5 In the case of pipes intended for essential services each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

11.7.6 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

11.7.7 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

11.7.8 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck, by means of metallic bulkhead or deck pieces. The bulkhead pieces are to be protected against corrosion, and so constructed to be of a strength equivalent to the intact bulKhead: attention is drawn to 11.7.1. Details of the arrangements are to be submitted for approval.

11.7.9 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 10, Ch 1,1.12.

11.8 Testing

11.8.1 The hydraulic testing of pipes and fittings is to be in accordance with Section 7.

11.8.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ. *See also* Pt 10, Ch 1,20.2.3.

■ *Section 12* **Valves**

12.1 Design requirements

12.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of 12.1.2 to 12.1.8 are to be satisfied.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, they are to be of all-metallic construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut, unless this is readily obvious. Legible nameplates are to be fitted.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.8 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

■ *Section 13* **Flexible hoses**

13.1 General

13.1.1 Short joining lengths of flexible hoses of approved type may be used, where necessary to accommodate relative movement between various items of machinery connected to permanent piping systems.

13.1.2 For the purpose of approval for the applications in 13.2, details of the materials and construction of the hoses, and the method of attaching the end fittings are to be submitted for consideration. The materials used in the construction of flexible hoses are to be suitable for the intended purposes.

13.1.3 In general, the use of hose clips as a means of securing the ends of hoses is to be restricted to the engine cooling water system, where the hose consists of a short, straight length joining two metal pipes, between two fixed points on the engine.

13.1.4 Prototype pressure tests are to be carried out on each new type of hose, complete with end fittings, and in no case is the bursting pressure to be less than five times the maximum working pressure in service.

13.1.5 In machinery spaces and other locations where sources of ignition are present, flexible hoses intended for use in systems containing flammable liquids are to be of approved fire resisting materials in compliance with an acceptable standard. Hoses complete with the attachments are to be type tested to verify fire resistance.

13.2 Applications

13.2.1 Synthetic rubber hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in 14.2.4.

13.2.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, fuel oil, lubricating oil and hydraulic oil systems. Where synthetic rubber hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

13.2.3 Flexible hoses may also be used to accommodate the effects of shock where associated with defined military requirements. *See* Pt 1, Ch 2,4.8 and 4.10.

■ *Section 14* **Expansion pieces**

14.1 Design and construction requirements

14.1.1 The design and construction of expansion pieces for intended for installation in piping systems is to be in accordance with an acceptable standard or design code appropriate to the piping system. Where suitable standards are not available, details of materials and construction are to be submitted for consideration. Where expansion pieces are fitted, the requirements of this section are to be satisfied.

14.1.2 The design of expansion pieces is to take account of pressure, temperature, fluid compatibility, loads to accommodate axial and lateral movements and fatigue life due to vibration.

14.1.3 Prototype pressure tests are to be carried out on each new type of expansion piece, and in no case is the burst pressure to be less than four times the design pressure.

14.1.4 For requirements relating to testing after manufacture, *see* Section 16.

14.2 Applications

14.2.1 Expansion pieces of an acceptable design are only to be used in permanent piping system installations to accommodate axial and lateral movements. They are not to be used to compensate for piping misalignment unless specifically designed for the purpose.

14.2.2 Expansion pieces are to be used within their specified pressure, temperature and movement conditions for all normal operating conditions. The design and operating ratings of expansion pieces are not to be less than that of the piping system in which the expansion piece is installed.

14.2.3 Expansion pieces used in compressed air, boiler feed water, steam and flammable oil piping systems are to be of steel or other approved material.

14.2.4 Expansion pieces incorporating oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea-water lines, they are to be provided with guards which effectively enclose, but do not interfere with, the action of the expansion pieces and will reduce to a minimum practicable, any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines in other services, including, ballast lines in machinery spaces and inside water ballast tanks, and bilge lines in enclosed spaces only, will be specially considered when plans of the piping systems are submitted for approval.

14.2.5 Expansion pieces are to be installed in accordance with the manufacturer's instructions and are to be protected against over extension and over compression. The adjoining pipes are to be suitably aligned, supported and anchored. Where necessary, expansion pieces of bellows expansion pieces are to be protected against mechanical damage.

■ *Section 15* **Pumps**

15.1 General

15.1.1 The design, construction and operational capability of all pumping units is to be suitable for operating conditions in Pt 1, Ch 2,4. The selection of pumping units is to recognise the following details:

(a) Pump characteristic and required duty.
(b) Performance if required to perform a secondary duty.
(c) Pumped fluid and its temperature ranges.
(d) Maximum discharge pressure head from the pump and design pressure of piping system.
(e) The size of air pipes and capacity of air pipe heads fitted to tanks which can be pumped up.
(f) The need to fit relief devices to pumps and piping systems.
(g) Maximum permissible fluid velocities in the piping system to avoid erosion and damage to valve seats and other fittings.
(h) Minimum fluid velocities to avoid fouling and subsequent pitting.

15.1.2 Pumps employed in bilge pumping systems are to have a means of priming and this is to be independent of the pump sea inlet connection.

■ *Section 16* **Testing**

16.1 Hydraulic tests before installation on board

16.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor's satisfaction. Further, all steam, feed, compressed air and fuel oil pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 3,5 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

16.1.2 Where the design temperature does not exceed 300°C, the test pressure is to be 1,5 times the design pressure, as defined in 3.3.

16.1.3 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300°C, the test pressure is to be as follows:

(a) For carbon and carbon-manganese steel pipes, the test pressure is to be twice the design pressure, as defined in 3.3.
(b) For alloy steel pipes, the test pressure is to be determined by the following formula, but need not exceed $2p$:

$$p_t = 1{,}5 \frac{\sigma_{100}}{\sigma} p \quad \text{bar}$$

where

p_t, and p are as defined in 3.2.1
σ = permissible stress for the design temperature, in N/mm^2, as stated in Table 1.6.2
σ_{100} = permissible stress for 100°C, in N/mm^2, as stated in Table 1.6.2.

16.1.4 Where alloy steels not included in Table 1.6.2 are used, the permissible stresses will be specially considered, as indicated in 6.1.2.

16.1.5 Consideration will be given to the reduction of the test pressure to not less than $1{,}5p$, where it is necessary to avoid excessive stress in way of bends, branches, etc.

16.1.6 All valve bodies are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating at ambient temperature. However, the test pressure need not be more than 70 bar above the design pressure specified for the design temperature.

16.1.7 In no case is the membrane stress to exceed 90 per cent of the yield stress at the testing temperature.

16.2 Testing after assembly on board

16.2.1 Heating coils in tanks, gas fuel and oil fuel piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar.

16.2.2 Where pipes specified in 16.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 8.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

16.2.3 The hydraulic test required by 16.2.2 may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

16.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, the pipes after fitting are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

16.2.5 Each flexible hose assembly and expansion piece intended for use with flammable liquids is to be provided with a certificate of hydrostatic pressure testing and conformity of production.

16.2.6 Where flexible hoses, mechanical pipe connections and/or expansion pieces are used in bilge, dewatering, sea water or flammable liquid piping systems, the pipe system is to be hydraulically tested to 1,5 times the design pressure or 7 bar whichever is the greater.

16.2.7 Pumps essential for the propulsion or safety of the ship are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating at ambient temperature.

■ *Section 17* Guidance notes on metal pipes for water service

17.1 General

17.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

17.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

17.2 Materials

17.2.1 Materials used in sea-water piping systems include:

- Galvanized steel.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

17.2.2 Selection of materials should be based on all of the following:

- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered.
- Compatibility with the other materials in the system, such as valve bodies and casings, e.g. in order to minimise bimetallic corrosion.
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitization of cast iron, the ability to resist stress corrosion and corrosion fatigue.
- The amenability to fabrication by normal practices.

17.3 Steel pipes

17.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

17.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

17.3.3 Galvanizing the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

17.3.4 Austenitic stainless steel pipes are not recommended for salt-water services as they are prone to pitting, particularly in polluted waters.

17.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

17.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

17.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

17.4 Copper and copper alloy pipes

17.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

17.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

17.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

17.5 Flanges

17.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

17.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

17.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

17.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

17.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

17.5.6 The use of a copper-zinc brazing alloy is not permitted.

17.6 Water velocity

17.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

17.6.2 The water velocity in copper pipes should not exceed 1 m/s.

17.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

- Galvanized steel 3,0 m/s
- Aluminium brass 3,0 m/s
- 90/10 copper-nickel-iron 3,5 m/s
- 70/30 copper-nickel 5,0 m/s

17.7 Fabrication and installation

17.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth. The following points should be observed:

(a) Short stiff bends are to be avoided, *see* 17.7.4.
(b) Pipe runs downstream of turbulence raising components such as reducing valves and orifices are to be straight and as long as practicable.
(c) Changes in pipe bore dimensions are to have a shallow taper transition.

17.7.2 Pipe bores should be smooth and clean.

17.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

17.7.4 Pipe bends should be of as large a radius as possible (in general, the radius of curvature at centreline is to be not less than three times the pipe outside diameter) and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

17.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

17.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

17.7.7 Strainers should be provided at the inlet to sea-water systems.

17.7.8 Where pipes and associated fittings are required to be thermally insulated after installation on board, the piping should be arranged to permit efficient application of insulating materials.

17.7.9 Non-ferrous piping should not be arranged within bilge wells or spaces. Where this is not possible, the piping should be suitably treated to avoid galvanic action in the bilge spaces.

17.8 Metal pipes for fresh water services

17.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

17.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanized, or pipes of suitable non-ferrous material used.

17.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

17.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

17.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in ‘once through’ systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

17.8.6 Piping systems for portable water are to be designed to avoid dead ends and other configurations that would lead to stagnant conditions.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for ship piping systems installed in naval ships for the watertight and weathertight integrity of the hull and spaces within the hull.

1.1.2 Attention is to be given to any relevant requirements of the Naval Authority.

1.1.3 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the piping system arrangements of small ships and ships to be assigned class notations for restricted or special services.

1.1.4 Where ship piping systems are required to satisfy requirements for the prevention of pollution, reference is to be made to the applicable requirements for **POL** and **EP** class notations. *See* Vol 3, Pt 3, Ch 6 and Vol 3, Pt 2, Ch 2.

1.2 Plans and particulars

1.2.1 At least three copies of the following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:

- Arrangements of air pipes and closing appliances to tanks and enclosed spaces.
- Sounding arrangements for all tanks and enclosed spaces
- Arrangements of level alarms fitted in tanks, machinery spaces and any other spaces.
- Arrangements of any cross-flooding or heeling tank systems.
- Bilge drainage and dewatering arrangements to all compartments which are to include details of location, number and capacity of pumping units on bilge and dewatering service.
- Ballast filling and drainage arrangements.
- Tank overflow arrangements.
- Details verifying compliance with the sizing of air pipes required by 10.8.
- Details verifying compliance with 10.3.3 for tanks that can be replenished at sea with design ship movements and filling rates stated.

1.3 Prevention of progressive flooding in damage condition

1.3.1 Precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage.

1.3.2 Where it is not practicable to locate piping systems as required by 1.3.1, the following precautions are to be taken:

(a) Bilge and dewatering suction pipes are to be provided with non-return valves of approved type.

(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the damage waterline where required by the Rules. These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.3.3 Where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of Chapter 1.

2.1.3 Materials sensitive to heat, such as aluminium or plastics, are not to be used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments. *See* Chapter 1 for plastics pipes.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with Chapter 1.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Valves – Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in ballast systems may be fitted inside tanks, subject to 2.3.2.

2.3.2 All valves which are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in ballast systems, as permitted by 2.3.1, local manual operation may be by extended spindle, a portable hand pump or similar energy device. Where manual operation is by hand pump or stored energy device, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump or stored energy device. Not less than two hand pumps or stored energy devices are to be available for each space where valves can be locally and remotely operated.

2.3.3 In case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead piece may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see* 3.3.3.

2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.5.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves for ship-side applications are to be installed such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air, *see* 2.5.5.

2.5.5 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating. Where alternative forms of attachment are proposed, details are to be submitted for consideration.

2.5.6 Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and, if valves are fitted, the hand wheels are to be suitably retained on the spindle.

2.5.7 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. Provision is to be made for preventing any discharge of water into rescue boats. The valve spindles are to extend above the lower platform, and the hand wheels of the main cooling water sea inlet and emergency drainage suction valves are to be situated not less than 460 mm above this platform.

2.5.8 Ship-side valves and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.9 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

2.5.10 Valves, cocks and distance pieces, intended for installation on the ship's side below the waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.5.11 For sea connections for ships having notation for ice navigation, *see* Vol 3, Pt 1, Ch 1.

2.6 Piping systems – Installation

2.6.1 Bilge, dewatering, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints are to be efficiently secured in position to prevent chafing or lateral movement. For joints in oil fuel piping systems, *see* Ch 3,4.5 and 4.6.

2.6.2 Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

2.6.3 Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes, *see* Ch 1,14.

2.8 Miscellaneous requirements

2.8.1 All pipes situated where they are liable to mechanical damage are to be efficiently protected.

2.8.2 So far as practicable, pipelines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of liquid, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see* 10.4.2.

2.9 Testing after installation

2.9.1 After installation on board, all steam, hydraulic, compressed air and other piping systems within the Mobility and Ship Type category together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

CROSS-REFERENCE

For guidance on metal pipes for water services, *see* Ch 1,17.

■ *Section 3*
Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All ships are to be provided with efficient dewatering arrangements having suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.1.2 The dewatering system arrangements are to be capable of draining any watertight compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.1.3 The requirements for dewatering system arrangements recognise that naval ships commonly use eductors for dealing with large amounts of water ingress into machinery spaces and other compartments.

3.1.4 Bilge piping systems for dealing with small amounts of oily water accumulation in machinery spaces and installed for the prevention of pollution of the sea by oil are not considered an effective means of dealing with large amounts of water ingress referred to in 3.1.3. The arrangement of valves and fittings are however to comply with the requirements of Section 7 for the prevention of communication between compartments.

3.1.5 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist. Depending on the quantities of such liquids carried, an additional means of drainage may be required for their compartments.

3.2 Tanks and cofferdams

3.2.1 All tanks (including double bottom tanks), whether used for ballast or oil fuel are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank. Ballast tanks may be drained by the use of eductors and filled by using a suitable sea water supply system. Where the sea water supply system for filling ballast tanks is used for other purposes, the availability of supply is to be sufficient for all operational requirements.

3.2.2 In general, the drainage arrangements are to be in accordance with 3.1. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.2.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the bilge or dewatering system.

3.3 Fore and after peaks

3.3.1 Fuel oil, lubrication oil and other flammable liquids are not to be carried in forepeak tanks.

3.3.2 Where the peaks are used as tanks, a power pump or suitable eductor suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.3.3 Where the peaks are not used as tanks, and bilge or dewatering suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps and in no case exceeds 7,3 m.

3.3.4 Pipes piercing the collision bulkhead are to be fitted with suitable valves operable from above the damage control deck and the valve chests are to be secured to the bulkhead inside the fore peak. The valves may be fitted on the after side of the collision bulkhead, provided that the valve is readily accessible under all service conditions.

3.4 Space above fore, after peaks and machinery spaces

3.4.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand pump, power pump or eductor suctions.

3.4.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand pump, power pump or eductor suctions.

3.4.3 Subject to special approval of any applicable subdivision requirements, compartments referred to in 3.3.2 that are adequately isolated from the adjacent tween decks, may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks situated in well lighted and visible positions.

3.5 Maintenance of integrity of bulkheads

3.5.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but closed to these spaces and drained by means of a suction of appropriate size led from the bilge or dewatering system through a screw-down non-return valve.

3.5.2 The scupper tank air pipe is to be led to above the bulkhead deck, and provision is to be made for ascertaining the level of water in the tank.

3.5.3 Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

3.5.4 No open ended drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

3.5.5 Where drain valves or cocks are fitted to bulkheads other than the collision bulkhead, as permitted by 3.5.4, the drain valves or cocks are to be at all times readily accessible and are to be capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut.

■ *Section 4*
Drainage of machinery spaces

4.1 General

4.1.1 The dewatering arrangements in the machinery spaces are to comply with 3.1, except that the arrangements are to be such that any water which may enter these compartments can be drained through at least two dewatering suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. The two means of drainage are to be capable of being operated independent of each other.

4.1.2 The drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

4.1.3 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

4.2 Separate machinery spaces

4.2.1 The two means of drainage required by 4.1.1 are to be located in not less than two watertight compartments.

4.3 Machinery space – Emergency drainage

4.3.1 In addition to the dewatering suctions detailed in 4.1, an emergency suction is to be provided in each main machinery space. This suction is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

4.3.2 The emergency suction is to be led to the largest available power pump, or an eductor which is not a dewatering unit required by 4.1.1. The emergency drainage suction is to be the same size as that of the pump suction-branch.

4.3.3 One suction from one of the two independent means of drainage required by 4.1.1 may be omitted on the same side of the ship where the emergency suction is fitted.

4.3.4 Emergency drainage suction valve nameplates are to be marked 'For emergency use only'.

■ *Section 5*
Size of dewatering suction pipes

5.1 Dewatering suctions

5.1.1 The diameter of dewatering suction pipes are to be selected to provide a water pumping speed of not less than 2 m/s. The internal diameter of pipes is to be not less than 50 mm.

■ *Section 6*
Drainage units on dewatering service and their connections

6.1 Number of pumping units

6.1.1 At least three power pumps for supply of water to eductors are to be provided in the machinery spaces.

6.1.2 Dewatering eductors may take suction from a suction main with branches to individual spaces or directly to individual spaces or a combination of systems.

6.2 General service pumps

6.2.1 The power pumps, required by 6.1 may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for dewatering duty when required.

6.3 Capacity of pumps and eductors

6.3.1 The capacity of each pump required by 6.1.1 is to be sufficient to supply the eductor capacities required by 6.3.2 and capable of providing water to eductors in any two compartments. Where the piping system supplying the eductors is used for other purposes, the capacity of the pumps is to be sufficient for those additional services.

6.3.2 The capacity of dewatering eductors are to be not less than required by the formulae in 6.3.3 or 6.3.4.

6.3.3 Where the eductor is connected to a suction main serving more than one compartment.

$$Q = \frac{16}{10^3} L (B + D) + 15 \quad (\text{m}^3/\text{h})$$

where
- B = greatest moulded breadth of ship, in metres
- D = moulded depth to assumed damage waterline, in metres
- L = length of compartments, in metres

In general the capacity is to be not less than 75 m^3/hr for ships over 100 m length.

6.3.4 Where an eductor is connected to a single suction in a machinery space or other space located below the damage waterline, the capacity is to be not less than:

$$Q = \frac{26}{10^3} C (B + D) + 15 \quad (\text{m}^3/\text{h})$$

where
- C = length of compartment, in metres
- B and D are as defined in 6.3.3.

6.3.5 The capacity of eductors for spaces other than required by 6.3.3 and 6.3.4 are in general to be not less than 15 m^3/h.

6.4 Pump and eductor connections

6.4.1 The connections at the power pumps and eductors are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.4.2 Pump units required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any units so connected is unaffected by the other units being in operation at the same time.

■ *Section 7* Pipe systems and their fittings

7.1 Prevention of communication between compartments

7.1.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another or machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge and dewatering valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main suction line.
- Direct bilge and dewatering suctions and bilge pump or eductor connections to main suction lines.

7.1.2 The valves and controls required for the drainage arrangements necessary for complying with 3.1.2 and 4.1.2 are to be capable of being operated from the damage control deck.

7.1.3 All valves and cocks mentioned in 7.7.1 and 7.7.2 which can be operated from the damage control deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

7.2 Isolation of bilge and dewatering systems

7.2.1 Bilge and dewatering pipes which are required for draining machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

7.3 Machinery space suction – Mud boxes

7.3.1 Suctions for bilge drainage and dewatering in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the suction wells and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency drainage suctions.

7.4 Compartment suctions – Strum boxes

7.4.1 The open ends of bilge and dewatering suctions in compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.5 Tail pipes

7.5.1 The distance between the foot of all bilge and dewatering tail pipes and the bottom of the suction well is to be adequate to allow a full flow of water and to facilitate cleaning.

7.6 Location of fittings

7.6.1 Bilge and dewatering valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms.

7.6.2 Provision is to be made to prevent the compartment served by any bilge or dewatering suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

7.6.3 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

7.7 Bilge and dewatering pipes in way of double bottom and deep tanks

7.7.1 Bilge and dewatering suction pipes are not to be led through double bottom or deep tanks if it is possible to avoid doing so.

7.7.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.8 Non-return valves

7.8.1 Where non-return valves are fitted to the open ends of bilge or dewatering suction pipes in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 8* Cross flooding arrangements

8.1 Cross flooding arrangements

8.1.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from the damage control deck.

■ *Section 9*
Additional requirements relating to fixed pressure fire-extinguishing systems

9.1 Bilge drainage requirements

9.1.1 Where arrangements for cooling underdeck hold spaces, or fire-fighting by means of fixed spraying nozzles or by flooding of spaces with water are provided, the drainage arrangements are to be such as to be effective under all normal angles of heel and trim. The following provisions are also to be satisfied:

(a) The drainage system is to be sized to remove no less than 125 per cent of the maximum water input through fire fighting systems on each side of the ship in each fire zone.

(b) The drainage system valves are to be operable from outside the protected space. The operating position is to be in the vicinity of the extinguishing system controls where such controls are fitted.

(c) Adequately sized bilge wells are to be located at the side shell of the ship at a distance of not more than 40 m in each watertight compartment, see also Vol 1, Pt 3 , Ch 4,7.1.4 and Vol 1, Pt 4, Ch 3,2.11. In ships other than NS3 Ships and vessels designed to carry less than 50 embarked personnel, if it is not possible to locate the bilge wells as required, the free surface effect on the ship's stability is to be determined and submitted to the Naval Authority for appraisal.

NOTE:
Normal angles of heel and trim are to be taken as:

1. Ship on an even keel or has a list of not more than 5°
2. Ship on even trim or is trimmed not more than 5° for a ship up to 100 m in length. Where the length of the ship exceeds 100 m, the maximum trim may be taken as 500/*L* degrees where *L* = length of ship in metres.
3. The angles of heel and trim may occur simultaneously.

9.1.2 If drainage of aircraft, vehicle or hold spaces is by gravity, the drainage is to be lead directly overboard or to a closed drain tank. If led overboard the scuppers are to comply with Vol 1, Pt 3, Ch 4,7.1.3(a) and (b). If led to a closed drain tank, this tank is to be located outside the machinery spaces and provided with a dedicated vent pipe leading to a safe location on the open deck. *See also* Vol 1, Pt 4, Ch 3,2.11.

9.1.3 Drainage from a space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the space above.

9.1.4 Magazines may have specific requirements for water input for fire protection purposes and the water drainage arrangements are to take these requirements into account. *See* Vol 1, Pt 4, Ch 1,6.9 and Vol 2, Pt 7, Ch 5,10.2.

■ *Section 10*
Air, overflow and sounding pipes

10.1 Materials

10.1.1 Air, overflow and sounding pipes are to be made of steel or other approved material. For use of plastics pipes of approved type, *see* Chapter 1.

10.1.2 Air, overflow and sounding pipes fitted above the weather deck are to be of steel or equivalent material.

10.2 Nameplates

10.2.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

10.3 Air pipes

10.3.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

10.3.2 The air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

10.3.3 For tanks that are capable of being replenished when the ship is at sea, the air pipe arrangements are to be such that account is taken of ship motions during filling operations. Such arrangements are typically to incorporate at least two air pipes, situated at diagonally opposite ends of the tank. *See also* Ch 3,4.11.3 and 4.18.10 for further requirements for fuel filling arrangements.

10.4 Termination of air pipes

10.4.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the assumed damage waterline. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, *see* Vol 1, Pt 3, Ch 4,6.2.

10.4.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

10.4.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

10.4.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rain water.

10.5 Gauze diaphragms

10.5.1 The open ends of air pipes to oil fuel tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

10.5.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe. *See* 10.8.

10.6 Air pipe closing appliances

10.6.1 The closing appliances fitted to tank air pipes in accordance with Vol 1, Pt 3, Ch 4,6.2 are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed.

10.6.2 Air pipe closing devices are to be of a type acceptable to Lloyd's Register (hereinafter referred to as 'LR') and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristics of the closing device is to determined using water. *See* 10.8.1.

10.6.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

10.7 Size of air pipes

10.7.1 For every tank which can be filled by the ship's pumps, replenishment at sea or from shore facilities, the total cross-sectional area of the air pipes and the design of the air pipe closing devices are to be such that when the tank is overflowing at the maximum pumping capacity or maximum delivery filling rate available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

10.7.2 In all cases, whether a tank is filled by ship's pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

10.7.3 Where tanks are fitted with cross flooding connections, the air pipes are to be of adequate area for these connections.

10.7.4 Air pipes are to be not less than 50 mm bore.

10.8 Overflow pipes

10.8.1 For all tanks which can be filled by the ship's pumps or by shore pumps, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipe is less than that required by 10.7.

(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

10.8.2 In the case of oil fuel and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means are to be provided to indicate when overflow is occurring, or when the contents reach a predetermined level in the tanks.

10.8.3 Overflow pipes are to be self draining under normal conditions of trim.

10.8.4 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality, adequately protected from mechanical damage and well lit.

10.10 Air and overflow systems

10.9.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point close to the assumed damage waterline.

10.9.2 The arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through the combined air pipes or the overflow main.

10.9.3 Where overflow from tanks which are used for the alternative carriage of oil and water ballast are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil.

10.9.4 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

10.10 Sounding arrangements

10.10.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

10.10.2 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

10.10.3 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

10.10.4 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

10.10.5 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, oil fuel or other flammable liquid, the glasses are to be of the flat type of heat-resisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

10.10.6 If means of sounding, other than a sounding pipe, is fitted in any ship for indicating the level of liquid in tanks containing oil fuel, lubricating oil or other flammable liquid, failure of such means or over filling of the tank should not result in the release of tank contents.

10.11 Termination of sounding pipes

10.11.1 Sounding pipes are to be led to positions above the assumed damage waterline which are at all times accessible and, in the case of oil fuel tanks, refuelling oil tanks, lubricating oil tanks and tanks containing other flammable oils, the sounding pipes are to be led to safe positions on the open deck.

10.11.2 For closing requirements, *see also* Vol 1, Pt 3, Ch 4,6.2.

10.12 Short sounding pipes

10.12.1 In machinery spaces and tunnels, in circumstances where it is not practicable to extend the sounding pipes as mentioned in 10.11, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Where such pipes serve tanks containing oil fuel or other flammable liquid, an additional sounding device of approved type is to be fitted. An additional sounding device is not required for lubricating oil tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks, other than double bottom tanks, will be the subject of special consideration.

10.12.2 Short sounding pipes to oil fuel and lubricating oil tanks, and other flammable oil tanks (flash point not less than 60°C) are to be fitted with cocks having parallel plugs with permanently attached handles, so loaded that, on being released, they automatically close the cocks. In addition a small diameter self-closing test cock is to be fitted below the cock mentioned above in order to ensure that the sounding pipe is not under a pressure of oil before opening up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

10.12.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

10.12.4 In ships that are required to be provided with a double bottom, short sounding pipes, where fitted to double bottom tanks, are in all cases to be provided with self-closing cocks as described in 10.12.2.

10.12.5 Where a double bottom is not required to be fitted, short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

10.13 Elbow sounding pipes

10.13.1 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any sub-division and damage stability requirements that may apply, *see* 1.3.1.

10.13.2 The elbows are to be of heavy construction and adequately supported.

10.14 Striking plates

10.14.1 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

10.14.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

10.15 Size of sounding pipes

10.15.1 Sounding pipes are to be not less than 32 mm bore.

10.15.2 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore.

CROSS-REFERENCES

For 'Ice Class' requirements, *see* Vol 3, Pt 1, Ch 1.
For control engineering equipment, *see* Pt 9, Ch 1.
For requirements relating to scuppers and sanitary discharges, *see* Vol 1, Pt 3, Ch 4.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for machinery piping systems installed in naval ships for the continuous and safe operation of main and auxiliary machinery and engineering systems.

1.1.2 In addition to the requirements detailed in this Chapter, the requirements of Chapter 1, Chapter 2, Sections 1 and 2 are to be complied with where applicable.

1.1.3 The requirements of Pt 2, Ch 1,7 are to be complied with for compressed air systems for starting of oil engines.

1.1.4 The requirements of Ch 2,3 are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.5 The requirements of Sections 2 and 4 are to be complied with, as far as they are applicable, for all flammable liquids.

1.1.6 The control and monitoring requirements for prime movers, transmission systems, propulsion devices, steering systems and boilers in Parts 2, 3, 4, 6 and 8 are also to be complied with where applicable.

1.1.7 Where reference is made to main auxiliary engines, the requirements are also applicable to main and auxiliary gas turbines.

1.2 Plans and particulars

1.2.1 Three copies of the following plans (in diagrammatic form) and particulars are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of novel or special character affecting classification.

- Arrangements of oil fuel bunkering, storage and transfer.
- Arrangements of oil fuel piping in connection with oil burning installations.
- Arrangements of any gas burning installations.
- Arrangement of boiler feed system.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangements of lubricating oil systems.
- Arrangements of flammable liquids used for power transmission, control and heating systems.
- Arrangements of non-flammable liquids used for power transmission and control systems in Mobility category and Ship Type category engineering systems.
- Arrangements of cooling water systems for main and auxiliary purposes.
- Oil fuel settling service and other oil fuel tanks not forming part of the ship's structure.
- Arrangements of steam systems for main and auxiliary services.
- Arrangements of incinerator systems.
- Arrangements of air intakes and exhaust gas piping for main and auxiliary machinery.
- Description of oil fuels with statement of minimum flash point (closed cup test).

1.2.2 *See* Pt 9, Ch 1 for details of plans to be submitted for control, monitoring and alarm systems.

■ *Section 2* Oil fuel – General requirements

2.1 Flash point

2.1.1 The flash point (closed cup test) of oil fuel for used in naval ships classed for unrestricted service is, in general, to be not less than 60ºC.

2.1.2 The use of fuel having a lower flash point than specified in 2.1.1 may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

2.1.3 In general, oil fuel in storage and service tanks is not to be heated to a temperature exceeding 10ºC below its flash point. Higher temperatures will be considered where:

(a) The tanks are vented to a safe position outside the engine room and, as in the case of all oil fuel tanks, the ends of the ventilation pipes are fitted with gauze diaphragms.

(b) Openings in the drainage systems of tanks containing heated oil fuel are located in spaces where no accumulation of oil vapours at temperatures close to the flash point can occur.

(c) There is no source of ignition in the vicinity of the ventilation pipes or near the openings in the drainage systems or in the tanks themselves.

2.1.4 The temperature of any heating medium is not to exceed 220°C.

2.2 Special fuels

2.2.1 When it is desired to carry a quantity of fuel having a flash point below 60°C for special services, e.g. aviation spirit for use in helicopters or vehicles, full particulars of the proposed arrangements are to be submitted for consideration, *see* Chapter 4.

2.3 Oil fuel sampling

2.3.1 Sampling points are to be provided at locations within the oil fuel system that enable samples of oil fuel to be taken in a safe manner.

2.3.2 The position of a sampling point is to be such that the sample of the oil fuel is representative of the oil fuel quality at that location within the system.

NOTE

Samples taken from sounding pipes are not considered to be representative of the tank's contents.

2.3.3 The sampling arrangements within the machinery space are to be capable of safely providing samples when machinery is running and are to be provided with isolating valves and cocks of the self-closing type. The sampling points are to be located in positions as far removed as possible from any heated surface or electrical equipment such as to preclude impingement of oil fuel onto such surfaces on equipment under all operating conditions, *see* Vol 2, Pt 1, Ch 2,4.5.

2.4 Ventilation

2.4.1 The spaces in which the oil fuel burning appliances and the oil fuel settling and service tanks are fitted are to be well ventilated and easy of access.

2.5 Boiler insulation and air circulation in boiler room

2.5.1 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks, and between the boilers and the sides of the storage tanks in which oil fuel and refuelling oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.5.2 Where water tube boilers are installed, there is to be a space of at least 760 mm between the tank top and the underside of the pans forming the bottom of the combustion spaces.

2.5.3 Smoke-box doors are to be shielded and well fitting, and the uptake joints made gastight. Where the surface temperature of the uptakes may exceed 220°C, they are to be efficiently lagged to minimize the risk of fire and to prevent damage by heat. Where lagging covering the uptakes, including flanges, is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

2.6 Funnel dampers

2.6.1 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning oil fuel only.

2.7 Heating arrangements

2.7.1 Where steam is used for heating oil fuel or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil.

2.7.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.7.3 Where it is proposed to use any heating medium other than steam or hot water, full particulars of the proposed arrangements are to be submitted for special consideration.

2.7.4 The heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and, after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of Ch 1,16.1.

2.7.5 Where electric heating elements are fitted means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220°C, *see* 9.5.

2.8 Temperature indication

2.8.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil. Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating ‘Do not remove unless tank/heater is drained’.

2.8.2 Controls are to be fitted to limit oil temperatures in oil storage and service tanks in accordance with 2.1.4 and in oil heaters to the maximum approved operating temperature, *see* 9.5.

2.9 Precautions against fire

2.9.1 As far as practicable, oil fuel tanks are to be part of the ship's structure and are to be located outside machinery spaces of Category A. Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of Category A, at least one of their vertical sides is to be joined to the machinery space boundaries. Such tanks are also preferably to have a common boundary with the double bottom tanks, and the area of a tank boundary common with the machinery spaces is to be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of Category A they are not to contain oil fuel having a flash point of less than 60ºC.

2.9.2 In general, the use of free-standing oil fuel tanks is to be avoided. Such tanks are prohibited in Category A machinery spaces on ships carrying more than 50 embarked personnel. Where free-standing tanks are permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized drain tank.

2.9.3 Tanks containing flammable liquids are not to be situated above or within one metre of engines, boilers, exhausts/uptakes or other highly heated surfaces.

2.9.4 Oil fuel pipes are not to be installed above or near high temperature equipment. Oil fuel pipes should also be installed and screened or otherwise suitably protected to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to Lloyd's Register (hereinafter referred to as 'LR'). Pipes are to be led in well lit and readily visible positions, *see also* Ch 2,2.8.2.

2.9.5 Pumps, heaters, filters and strainers and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filters and strainers is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved by either mechanically preventing the pressurized filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.9.6 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with Ch 2,10.12. For alternative sounding arrangements, *see* Ch 2,9.10.

2.9.7 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, oil fuel apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea-water.

2.9.8 Oil-tight drip trays of ample size having suitable drainage arrangements are to be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements or for valves which are so positioned that any leakage will drain directly into the bilges, *see* 2.9.4.

2.9.9 So far as is practicable, the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning oil fuel.

2.9.10 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners, and under all other oil fuel appliances which are required to be opened up frequently for cleaning or adjustment.

2.9.11 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable drain tank not forming part of the overflow system.

2.9.12 Separate oil fuel tanks are to be placed in an oil tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size.

2.10 Oil fuel contamination

2.10.1 The materials and/or their surface treatment used for the storage and distribution of oil fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in oil fuel piping systems where they may come into contact with the fuel is not permitted.

2.10.2 Corrosion resistant materials are to be used for oil fuel pipes between the treatment system required by 3.10.3 and the combustion system.

2.10.3 For prevention of ingress of water into oil fuel tanks via air pipes, *see* Ch 2,10.4.4.

2.10.4 The piping arrangements for oil fuel are to be separate and distinct from those intended for lubricating oil systems to prevent contamination of fuel oil by lubricating oil.

2.10.5 The piping arrangements for gas oil, distillate and diesel grades are to be separate and distinct from those intended for residual grades, up to the service tanks required by 4.17, to prevent cross-contamination. Cross-connection is permitted between separate arrangements in the event of failure of a designated item of equipment

Section 3 Oil fuel burning arrangements

3.1 Oil burning units

3.1.1 Where steam or thermal oil is required for the main propelling engines, for auxiliary machinery for essential services, or for heating of heavy fuel oil and is generated by burning oil fuel under pressure, there are to be not less than two oil burning units, each unit comprising a pressure pump, a suction filter, a discharge filter and a heater. For auxiliary boilers and thermal oil heaters, a single oil burning unit may be accepted, provided that alternative means, such as an exhaust gas heated boiler or heater, are available for supplying steam or thermal oil for essential purposes.

3.1.2 In two unit installations, each unit is to be capable of supplying fuel for generating all the steam or supplying all the thermal oil required for essential services.

3.1.3 In installations of three or more units, the capacities and arrangements of the units are to be such that all the steam or thermal oil required for essential services can be maintained with any one unit out of action.

3.1.4 Unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

3.2 Gravity feed

3.2.1 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use.

3.3 Starting-up unit

3.3.1 A starting-up oil fuel unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

3.3.2 Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with Pt 2, Ch 1,7.1.

3.4 Steam connections to burners

3.4.1 Where burners are provided with steam purging and/or atomizing connections, the arrangements are to be such that oil cannot find its way into the steam system in the event of valve leakage.

3.5 Burner arrangements

3.5.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil supply to that burner is shut-off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.6 Quick-closing valve

3.6.1 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

3.7 Top-fired boilers – Flame failure

3.7.1 In the case of top-fired boilers, means are to be provided so that, in the event of flame failure, the oil fuel supply to the burners is shut-off automatically, and audible and visual warnings are given. Any proposal to depart from this requirement in the case of small auxiliary top-fired boilers will be specially considered.

3.8 Spill arrangements

3.8.1 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut-off.

3.9 Alternately fired furnaces

3.9.1 For alternately fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

3.10 Oil fuel treatment for supply to diesel engines and gas turbines

3.10.1 Suitable fuel treatment plant that may include filtration, centrifuging and/or coalescing is to be provided to reduce the level of water and particulate contamination of the oil fuel to within the engine or gas turbine manufacturer's limits for inlet to the combustion system. The capacity and arrangements of the treatment plant is to be suitable for ensuring availability of treated oil fuel for the maximum continuous rating of the propulsion and electrical generating plant.

3.10.2 Two or more treatment systems are to be provided such that failure of one system will not render the other system(s) inoperative. Arrangements are to ensure that the failure of a treatment system will not interrupt the supply of clean oil fuel to diesel engines or gas turbines used for propulsion and electrical generator purposes. Any treatment equipment in the system is to be capable of being cleaned without interrupting the flow of treated fuel to supply the combustion system.

3.10.3 Centrifuges used for oil fuel treatment are to be type tested for their intended usage when installed on board a ship in accordance with a standard acceptable to LR.

3.10.4 Where heating of the oil fuel is required for the efficient functioning of the oil fuel treatment plant, a minimum of two heating units are to be provided. Each heating unit is to be of sufficient capacity to raise and maintain the required temperature of the oil fuel for the required delivery flow rate.

3.10.5 Heating units may be in circuit with separate treatment systems or provided with connections such that any heating unit can be connected to any treatment system.

3.10.6 Where heating of the oil fuel is required for combustion, not less than two pre-heaters are to be provided, each with sufficient capacity to raise the temperature of the fuel to provide a viscosity suitable for combustion.

3.10.7 Filters and/or coalescers are to be fitted in the oil fuel supply lines to each diesel engine and gas turbine to ensure that only suitably filtered oil is fed to the combustion system. The arrangements are to be such that any unit can be cleaned without interrupting the supply of filtered oil to the combustion system.

3.11 Booster pumps

3.11.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

3.11.2 The standby pump is to be connected ready for immediate use but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

3.12 Fuel valve cooling pumps

3.12.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 3.11.

■ *Section 4*
Oil fuel pumps, pipes, fittings, tanks, etc.

4.1 Transfer pumps

4.1.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use, or, alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

4.2 Control of pumps

4.2.1 The power supply to all independently driven oil fuel transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.3 Relief valves on pumps

4.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in close circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.4 Pump connections

4.4.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut-off for opening up and overhauling.

4.5 Pipes conveying heated oil

4.5.1 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

4.5.2 The flanges are to be machined, and the jointing material, which is to be impervious to oil heated to 150ºC, is to be the thinnest possible, so that flanges are practically metal to metal. The scantlings of the pipes and their flanges are to be suitable for a pressure of at least 13,7 bar or for the design pressure, whichever is the greater.

4.5.3 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions, provided these are of specially robust construction.

4.5.4 Flexible hoses of approved material and design may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board.

4.5.5 For requirements relating to flexible hoses, *see* Ch 1,13.

4.6 Low pressure pipes

4.6.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of steel, having flanged joints suitable for a working pressure of not less than 6,9 bar. The flanges are to be machined and the jointing material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired.

4.6.2 For requirements regarding bilge and dewatering pipes in way of double bottom tanks and deep tanks, *see* Ch 2,7.7.

4.7 Valves and cocks

4.7.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.7.2 All valves and cocks forming part of the oil fuel installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform. *See also* Ch 2,2.3.

4.7.3 Every oil fuel suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.8 Valves on deep tanks and their control arrangements

4.8.1 Every oil fuel suction pipe from a storage, settling and daily service tank situated above the double bottom, and every oil fuel levelling pipe within the boiler room or engine room, is to be fitted with a valve or cock secured to the tank.

4.8.2 The valves and cocks mentioned in 4.8.1 are to be capable of being closed locally and from positions outside these spaces. The remote controls are to be accessible in the event of fire occurring in the deep tank's space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions

4.8.3 The control for remote operation of the valve on the emergency generator fuel tank is to be in a separate location from the controls for the remote operation of other valves for tanks located in machinery spaces.

4.8.4 In the case of tanks of less than 500 litres capacity consideration will be given to the omission of remote controls.

4.8.5 Every oil fuel suction pipe which is led into the engine and boiler spaces, from a tank situated above the double bottom outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.8.2, except where the valve on the tank is already capable of being closed from an accessible position on the damage control deck.

4.8.6 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.8.2.

4.9 Water drainage

4.9.1 All oil fuel storage, settling and service tanks are to be provided with a means of removing water from the lowest point in the tank.

4.9.2 Open drains for removing water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.10 Relief valves on oil heaters

4.10.1 Relief valves are to be fitted on the oil side of heaters and are to be adjusted to operate at a pressure of 3,4 bar above that of the supply pump relief valve (*see* 4.3). The discharge from the relief valves is to be led to a safe position.

4.11 Filling arrangements

4.11.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.11.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11.3 The arrangements for filling oil fuel tanks are to be such that the tanks will not be subject to a pressure in excess of that for which they were designed. Maximum filling rates are to be stated in the ship's Operations Manual.

4.12 Transfer arrangements

4.12.1 Provision is to be made for the transfer of oil fuel from any oil fuel storage or settling tank to any other oil fuel storage or settling tank in the event of fire or damage.

4.13 Alternative carriage of oil fuel and water ballast

4.13.1 Where it is intended to carry oil fuel and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the oil fuel transfer pump are to be so arranged that the oil may be pumped from any one compartment by the oil fuel pump at the same time as the ballast pump is being used on any other compartment.

4.13.2 Attention is drawn to the requirements of the Naval Authority in connection with prevention of pollution of the sea by oil.

4.14 Deep tanks for the alternative carriage of oil or water ballast

4.14.1 In the case of deep tanks which can be used for the carriage of oil fuel or water ballast, provision is to be made for blank flanging the oil and water ballast filling and suction pipes.

4.15 Fresh water piping

4.15.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through fresh water tanks.

4.16 Independant/separate oil fuel tanks

4.16.1 Where separate oil fuel tanks are permitted, their construction is to be in accordance with the requirements of 4.16.2 to 4.16.6. *See also* 2.9.1 and 2.9.2.

4.16.2 In general, the minimum thickness of the plating of service, settling and other oil tanks, where they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

4.16.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in Table 3.4.1. The stiffeners are to be of approved dimensions.

Table 3.4.1 Plate thickness of separate oil fuel tanks

Thickness of plate, mm	Head from bottom of tank to top of overflow pipe, metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, mm				
5	585	525	—	—	—
6	725	645	590	—	—
7	860	770	700	650	—
8	1000	900	820	750	700
10	1280	1140	1040	960	900

4.16.4 The dimension given in Table 3.4.1 for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, wash-plates or the boundary of the tank.

4.16.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, horizontal stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

4.16.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.17 Oil fuel service tanks

4.17.1 An oil fuel service tank is a an oil fuel tank which contains only the required quality of fuel ready for immediate use.

4.17.2 Two oil fuel service tanks, for each type of fuel used on board, necessary for propulsion and generator systems, are to be provided. Each tank is to have a capacity for at least eight hours operation at sea, at maximum continuous rating of the propulsion plant and/or generating pant associated with that tank.

4.17.3 A greater or lesser period than the 8 hour period specified in 4.17.2 may be considered in conjunction with the operational requirements of the Naval Authority and any assigned Service Restriction.

4.18 Water compensated oil fuel tanks

4.18.1 The use of water compensated oil fuel tanks is to be avoided whenever practicable and attention is drawn to regulations that may be specified by the Naval Authority in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*.

4.18.2 Where the ship design considerations require the inclusion of seawater compensated oil fuel tanks the arrangements are to comply with the requirements in 4.18.3 to 4.18.13. Acceptance of water compensated oil fuel tanks is subject to the provision of alternative oil fuel storage and usage arrangements that do not rely only on the use of water compensated tanks and that permit oil fuel to settle before use. The arrangement and capacity of oil fuel in tanks that do not have seawater compensation arrangements are to recognise the service profile required by Pt 1, Ch 2,3.3.2 and be acceptable to the Naval Authority.

4.18.3 Tank types to be used as seawater compensated fuel tanks are listed in order of preference below. Preference is based on tank shape and the ability to readily pump out the contents:
(a) Wing or deep tanks.
(b) Wing double bottom tanks.
(c) Flat double bottom tanks.

4.18.4 The tank design is to limit the oil/water interface to reduce mixing to the minimum.

4.18.5 The internal structure of tanks is to allow free drainage to the lowest part of the tanks.

4.18.6 The tank internal preservation is to be suitable for both seawater and oil fuel and capable of resisting micro-biological contamination, specifically sulphate reducing bacteria.

4.18.7 All tanks are to have vertical longitudinal partitions (either of the fixed structural or flexible membrane type) with provision for sequential displacement of fluids in partitioned sections. The partitioned section furthest from the suction is to be provided with a suitable air pipe.

4.18.8 Means are to be provided to detect the fuel/water interface to allow accurate detection of remaining fuel in tanks.

4.18.9 The piping arrangements at the filling and discharge points are to be designed to minimise fluid turbulence.

4.18.10 The design oil fuel filling and seawater discharge flow rates are to be agreed by the Naval Authority. The oil fuel filling rate is to be achieved by use of filling trunks or other regulating method that will always provide sufficient head of oil to displace water from the water compensated fuel tanks and prevent a tank being subjected to a pressure greater than that for which it has been designed.

4.18.11 The discharge of seawater is to be via either:
(a) A high level discharge point above waterline for discharge to shore or lighter.
(b) Low level discharge just below waterline for discharging at sea.
Means are to be provided to ascertain actual discharge of sea-water at a position close to the ship-side discharge valve.

4.18.12 Header tanks for supply of seawater to water compensated oil fuel tanks are to be provided with level indication that can be readily sighted. Where the HP sea-water main is used to supply the header tanks, arrangements are to be made to prevent the oil tanks being subject to a pressure that exceeds the design pressure. Arrangements are also to be made to ensure that oil does not enter a header tank.

4.18.13 Where a water compensated oil fuel storage system is required to be capable of displacing oil fuel direct to a service tank in the event of a transfer pump or centrifuge failure, testing is to be carried out to demonstrate that the specified transfer rate can be achieved.

4.19 Arrangements for fuels with a flash point between 43° and 60°

4.19.1 Fuel oil tanks other than those in double bottom compartments are to be located outside Category A machinery spaces, *see also* Vol 1, Pt 3, Ch 2,4.10.

4.19.2 Provisions are to be made for the measurement of oil fuel temperature at the pump suction pipe.

4.19.3 Stop valves are to be provided at the inlet and outlet side of oil fuel strainers.

4.19.4 Pipe joints are to be either welded or spherical type union joints.

■ *Section 5* Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see* Ch 1,14.2.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.3 Reduced pressure lines

5.3.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect against excessive pressure.

■ *Section 6* Boiler feed water and condensate systems

6.1 Feed water piping

6.1.1 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for essential services. In the case of steam/steam generators, one means of feed will be accepted provided steam for essential services is available simultaneously from another source.

6.2 Feed pumps

6.2.1 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

6.2.2 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

6.2.3 The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of the non-return type.

6.3 Condensate pumps

6.3.1 Two or more extraction pumps are to be provided for dealing with the condensate from the main and auxiliary condensers, at least one of which is to be independently driven. Where one of the independent feed pumps is fitted with direct suctions from the condensers and a discharge to the feed tank, it may be accepted for this purpose.

6.4 Valves and cocks

6.4.1 Feed and condensate pumps are to be provided with valves or cocks, interposed between the pumps and the suction and the discharge pipes, so that any pump may be opened up for overhaul while the others continue in operation.

6.5 Reserve feed water

6.5.1 All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water.

6.5.2 For main boilers, one or more evaporators, of adequate capacity, are also to be provided.

CROSS-REFERENCE

For feed water level regulators for water tube boilers, *see* Pt 8, Ch 1,16.8.

■ *Section 7* Engine cooling water systems

7.1 General

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.1.2 In the case of main steam turbine installations, a sea inlet scoop arrangement may replace the main sea-water circulating pump, subject to the conditions stated in 7.2.2(c).

7.2 Standby supply

7.2.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.2.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.

(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.

(c) Where a sea inlet scoop arrangement is fitted, and there is only one independent condenser circulating pump, a further pump, or a connection to the largest available pump suitable for circulation duties, is to be fitted to provide the second means of circulation when the ship is manoeuvring. The pump is to be connected ready for immediate use.

(d) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.

(e) Where each auxiliary is fitted with a cooling water pump, standby means of cooling need not be provided.

Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.3 Selection of standby pumps

7.3.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc., are to be protected by an approved device against inadvertent over-pressure. *See* Pt 1, Ch 2,9.4.4 for the hydraulic test pressure which condensers are required to withstand.

7.4 Relief valves on main cooling water pumps

7.4.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system. For location of relief valves, *see* Ch 2,7.6.

7.5 Sea inlets

7.5.1 Not less than two sea inlets are to be provided for the pumps supplying the sea-water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.5.2 Where standby pumps are not connected ready for immediate use (*see* 7.2.2(b)), the main pump is to be connected to both sea inlets.

7.5.3 Cooling water pump sea inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

7.5.4 The auxiliary cooling water sea inlets are to be located one on each side of the ship.

7.6 Strainers

7.6.1 Where sea-water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

7.7 Cooling systems

7.7.1 Means are to be provided for the drainage and storage of engine coolants to enable maintenance and repair of the engine.

7.7.2 All cooling systems are to be provided with means of venting air at high points and sufficient drain fittings to enable the system to be completely drained for maintenance.

CROSS-REFERENCE

For guidance on metal pipes for water services, *see* Ch 1,17.

■ *Section 8* Lubricating oil systems

8.1 General requirements

8.1.1 In addition to the requirements detailed in this Section, the requirements of Sections 2 and 4 are to be complied with in so far as they are applicable. In all cases 2.8.1 to 2.8.4 and 4,2 4.3, 4.5, 4.8, 4.11 and 4.16 are to apply.

8.2 Pumps

8.2.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 370 kW.
(b) One main engine with its own pump is fitted and the output of the engine exceeds 370 kW.
(c) More than one main engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 370 kW.

8.2.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use. In all cases satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

8.2.3 Similar provisions to those of 8.2.1 and 8.2.2 are to be made where separate lubricating oil systems are employed for piston cooling, reduction gears, oil operated couplings, controllable pitch propellers, water jet systems and propulsion thrusters, unless approved alternative arrangements are provided.

8.2.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.3 Alarms

8.3.1 All main and auxiliary engines and turbines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.4 Emergency supply for propulsion turbines and propulsion turbo-generators

8.4.1 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

8.4.2 The emergency supply may be obtained from a gravity tank containing sufficient oil to maintain adequate lubrication for not less than six minutes, and, in the case of propulsion turbo-generators, until the unloaded turbine comes to rest from its maximum rated running speed.

8.4.3 Alternatively, the supply may be provided by the standby pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a
failure in the power supply.

8.4.4 For automatic shut-down arrangements of main turbines in the event of failure of the lubrication system, *see* Pt 2, Ch 2,5.1 and Ch 3,4.3.

8.5 Maintenance of bearing lubrication

8.5.1 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined under the conditions as shown in Pt 1, Ch 2,4.5.

8.5.2 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see* Pt 10, Ch 1,1.9.

8.5.3 Where a filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

8.5.4 The capacity of lubricating oil service tanks is to be sufficient to avoid the need to replenish a tank for an agreed period of time (Designer/Owner/Operator), assuming the normal oil consumption rate quoted by the equipment manufacturer.

8.6 Filters

8.6.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for special consideration.

8.6.2 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters. Generally, the openings in the filter elements are to be not coarser than required by the manufacturer of the turbines, especially for the supply to turbine thrust bearings.

8.7 Cleanliness of pipes and fittings

8.7.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.8 Lubricating oil drain tank

8.8.1 Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drainpipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform.

8.9 Lubricating oil contamination

8.9.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contamination or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

8.9.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated run-down lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements and procedures are to be in accordance with the equipment manufacturer's procedures and recommendations.

8.9.3 For prevention of ingress of water into lubricating oil tanks via air pipes, *see* Ch 2,10.4.4.

8.9.4 The design and construction of engine and gear box piping arrangements are to prevent contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where the engines or gearboxes are partly installed below the lower platform. Where flexibility is required to accommodate movement between the engine and sump tank, any flexible joint assembly is to be of an approved type suitable for its intended application.

8.9.5 Where there is a permanently attached oil filling pipe and cap provided for an engine or other item of machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer to prevent unwanted matter getting into the lubricating oil system. The caps are to be capable of being secured in the closed position.

8.9.6 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.10 Security

8.10.1 All valves whose position can affect the supply of oil to lubrication consumers are to be capable of being secured in their operating position.

8.10.2 All means of entry into lubricating oil tanks and gearcases are to be provided with a means of being locked in the closed position.

8.10.3 Drain plugs and cocks in lubricating systems are to be capable of being secured in the closed position.

8.11 Deep tank valves and their control arrangements

8.11.1 The requirements for remote operation on valves on deep tank suction pipes may be waived where the valves are closed during normal operation where agreed by the Naval Authority.

8.11.2 Remotely operated valves on lubricating oil deep tank suctions should not be of the quick-closing type where inadvertent use would endanger the safe operation of the main propulsion and essential auxiliary machinery.

CROSS-REFERENCES

For air, sounding pipes and gauge glasses, *see* Ch 2,10.
For hydraulic power actuating systems, *see* Ch 5,11

■ *Section 9*
Control, supervision and monitoring of equipment

9.1 General

9.1.1 The control and monitoring systems are to comply with the requirements of Pt 9, Ch 1.

9.2 Automatic and remote controls

9.2.1 Where equipment is fitted with automatic or remote control so that under normal operating conditions it does not require manual intervention by operators, it is to be provided with alarms and safety arrangements required by 9.3 to 9.5.

9.2.2 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.2.3 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.3 Thermal fluid heaters

9.3.1 Alarms and safeguards are indicated in 9.3.2, 9.3.3 and Table 3.9.1.

Table 3.9.1 Thermal fluid heaters: Alarms and safeguards

Item	Alarm	Note
Expansion tank level	Low	Oil fuel burners to be shut off automatically
Thermal fluid flow	Low	Oil fuel burners to be shut off automatically
Thermal fluid pressure	Low	Oil fuel burners to be shut off automatically
Thermal fluid outlet temperature	1st stage High	—
	2nd stage High	Oil fuel burners to be shut off automatically. *See* 9.2.3
Combustion air pressure	Low	Oil fuel burners to be shut off automatically.
Oil fuel pressure	Low	—
Oil fuel temperature or viscosity	High and low	Heavy oil only
Oil fuel atomizing steam/air pressure	Low	—
Burner flame and ignition	Failure	Each burner to be monitored. Oil fuel to burners to be shut off automatically. *See* Note 1
Uptake temperature	High	Where applicable, to monitor for soot fires

NOTES
1. Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.
2. Special consideration may be given to the requirements for oil fired hot water heaters.

9.3.2 The standby pumps for oil fuel and thermal fluid circulation are to start automatically when the discharge pressure from the working pump falls below a predetermined value.

9.3.3 The following heater services are to be fitted with automatic controls so as to maintain steady state conditions throughout the operating range of the heater:
(a) Combustion system.
(b) Oil fuel supply temperature or viscosity, heavy oil only.
(c) Thermal fluid temperature.

9.4 Incinerators

9.4.1 Alarms and safeguards are indicated in 9.4.2, 9.4.3 and Table 3.9.2.

Table 3.9.2 Incinerators: Alarms and safeguards

Item	Alarm	Note
Oil fuel temperature or viscosity	High and low	Heavy oil and sludge
Oil fuel pressure	Low	—
Combustion air pressure	Low	Oil fuel and/or sludge to burners to be shut off automatically
Burner flame and ignition	Failure	Oil fuel and/or sludge to burners to be shut off automatically. *See* Note
Furnace temperature	High	Oil fuel and/or sludge to burners to be shut off automatically
Furnace temperature	Low	If applicable
Exhaust temperature	High	—

NOTE
Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.

9.4.2 Where arrangements are provided to introduce solid waste into the furnace these are to be such that there is no risk of a fire hazard.

9.4.3 The combustion temperature is to be controlled to ensure that all liquid and solid waste is efficiently burned without exceeding predetermined temperature limits.

9.5 Miscellaneous machinery

9.5.1 Alarms and safeguards are indicated in 9.5.2 to 9.5.5 and Table 3.9.3.

9.5.2 **Dual fuel systems.** Oil and gas dual fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

9.5.3 **Oil heaters.** Oil fuel or lubricating oil heaters are to be fitted with a high temperature alarm which may be incorporated in the temperature control system. In addition to the temperature control system, an independent sensor, with manual reset, is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating medium remains limited to a value below 220°C.

Table 3.9.3 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	—
Daily service oil fuel tanks level	High and low	One high level alarm may be fitted in a common overflow tank
Daily service oil fuel tanks temperature	High	Where heating arrangements are fitted
Oil fuel settling tanks temperature	High	Where heating arrangements are fitted
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Purifier water seal broken	Fault	—
Purifier oil inlet temperature	High	—
Air compressor lubricating oil	Failure	Automatic shutdown
Air compressor discharge air temperature	High	—
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	
Oil heater temperature	High	*See also* Pt 7, Ch 3
Controlled environmental conditions	Abnormal	*See also* 9.2.2

9.5.4 **Oil tank electric heating.** Oil fuel and lubricating oil tanks that are provided with electric heating elements are to be fitted with a high temperature alarm, which may be incorporated in the temperature control system, a low level alarm and an additional low level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

9.5.5 **Oil fuel tanks.** Means are to be provided to eliminate the possibility of overflow from daily service oil fuel tanks into the machinery space and to safeguard against overflow of oil from the daily service oil fuel tanks through the air pipe. *See* Pt 7, Ch 2 regarding the termination of air pipes.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for piping systems and arrangements in naval ships for bunkering, storing and distribution of fuel for aircraft/helicopters and diesel engined vehicles that are part of the ship's operational equipment. The requirements are not applicable to the storage of petrol.

1.1.2 In addition to the requirements detailed in this Chapter, the requirements of Chapter 1 and Chapter 2, Sections 1, 2 and 10 are to be complied with where applicable.

1.1.3 The requirements of Ch 2,3 are also to be complied with, so far as they are applicable for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.4 The requirements address refuelling systems where the flash point of the fuel is:
(a) not less than 60ºC (closed cup test);
(b) less than 60ºC (closed cup test).

1.1.5 The requirements of the Naval Authority are also be taken into consideration. NATO interoperability, if any, are to be specified by the Owner/Operator.

1.1.6 Electrical arrangements are to comply with Pt 10, Ch 1 as applicable. Attention is drawn to Section 13 where it is intended to carry fuel with a flash point not exceeding 60ºC.

1.2 Plans and particulars

1.2.1 The following plans and particulars are to be submitted for approval.
- Description of fuel with statement of minimum flash point (closed cup test).
- Arrangement of fuel storage and piping.
- Storage tanks not forming part of the ship's structure.
- Arrangements for drainage, ventilation and sounding of spaces adjacent to storage tanks where the flash point is less than 60º C.
- Details of pumping units.
- Arrangements for testing and increasing the flash point of low flash fuel from aircraft/helicopters for transfer into the ship's storage system.
- Arrangements for gas analysing arrangements required by 3.1.5.
- Arrangements for stripping water from storage tanks.
- Arrangements for emergency cross connections between aircraft/helicopter and ship's fuel systems.

1.2.2 **Design statement**. A design statement that details the system capability and functionality under defined operating and emergency conditions is to be submitted for information.

1.2.3 **Operating manuals**. Operating manuals are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') for information and provided on board. The manuals are to include the following information:
(a) Particulars and description of systems and arrangements for bunkering, fuelling and defuelling aircraft/helicopters and vehicles.
(b) Operating instructions for the systems.

■ *Section 2* Refuelling facilities

2.1 Fuel storage

2.1.1 When it is intended to store fuel with a flash point less than 60ºC, the requirements of 2.1.2 to 2.1.12 are to be complied with.

2.1.2 Storage tanks are to be located in a designated area as remote as practicable from machinery and accommodation stations and be suitably isolated from areas where there are sources of ignition.

2.1.3 The storage and handling area is to be permanently marked. Instructions for filling fuel are to be posted in the vicinity of the filling area.

2.1.4 Storage tanks are to be protected from aircraft/helicopter crashes, mechanical damage, solar radiation and high temperatures as a result of a fire occurring in an adjacent area. Where applicable, storage tanks are also to be protected from radar and HF radio effects.

2.1.5 Storage tanks are to be of an approved construction and attention is to be given to inspection procedures, mounting and securing arrangements and electrical bonding of tanks and fuel transfer system. The internal surfaces of steel tanks are to be suitably coated with impervious paint to prevent corrosion. The coating is to comply with 2.5.1. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and should comply with the relevant Codes for the transportation of dangerous goods in ships.

2.1.6 Tank ventilation pipes are to be fitted with an approved type of vent head with pressure-vacuum valve and flame arrester. The vent outlet is to be located in a safe position away from accommodation spaces, ventilation intakes and equipment that may constitute an ignition hazard.

2.1.7 Fuel storage and handling areas are to be provided with collection trays of suitable capacity for containing leakage from tanks, pump units and other equipment that requires opening up for maintenance, and for draining any such leakage to a tank or container located in a safe area. For tanks forming an integral part of the ship's structure, cofferdams are to be provided as necessary to contain leakage and prevent contamination of the fuel.

2.1.8 Tanks are to be provided with an intrinsically safe level indicator that is fitted through the top of the tank.

2.1.9 Cofferdams are to provided between tanks and non-dangerous spaces, such as machinery spaces. (For guidance of definitions of dangerous spaces refer to Pt 10, Ch 1).

2.1.10 The cofferdam is to be provided with permanently fitted gas detectors, and a permanent ventilation system.

2.1.11 Drainage of the cofferdam space is to be entirely separate from the machinery space drainage arrangements.

2.1.12 The air pipe for the cofferdam space is to led to the open in a safe space and fitted with an approved air pipe head having a wire gauze diaphragm of incorrodible material.

2.1.13 Where it is intended to store fuel having a flash point not less than 60ºC, the arrangements are to be in accordance with 2.1.3, 2.1.4, 2.1.5, 2.1.7 and with the applicable requirements of Chapters 2 and 3.

2.1.14 In addition to the particular requirements relating to the storage of fuel having flash points greater or less than 60ºC as identified in 2.1.1 and 2.1.13, the requirements of 2.1.15 to 2.1.19 are also to be complied with for all fuels.

2.1.15 Storage tanks are to be provided with stripping arrangements to facilitate the removal of water.

2.1.16 A separate tank is to be provided to collect stripping and system drains and is to be arranged such that it can be drained to a fuel recovery tank.

2.1.17 Means are to be provided to eliminate the possibility of overflow from storage tanks into spaces where there are sources of ignition and to safeguard against overflow from the tanks through the air pipes. High level alarm arrangements are to be provided to indicate when fuel storage tanks have been filled in excess of maximum operating levels. In addition, low level alarm arrangements are to be provided for storage tanks capable of supplying fuel to refuelling systems.

2.1.18 The use of water compensated fuel tanks for fuel supply to aircraft and helicopters is not permitted. Wherever practicable they are to be avoided for fuel supply to diesel engined vehicles. Attention is drawn to regulations that may be specified by the Naval Authority in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*. Where ship design considerations require the use of such tanks, the requirements of Ch 3,4.18 are applicable.

2.1.19 *See* Pt 10, Ch 1,1.12 for requirements for control of static electricity.

2.2 Fuel pumping and filling

2.2.1 The pumping and filling arrangements are to comply with the requirements of 2.2.2 to 2.2.14.

2.2.2 Tank outlet valves and filling valves located below the top of the tank are to be mounted directly onto the tank and are to be capable of being closed from a remote location outside the compartment in the event of a fire in the compartment. Ball valves are to be of the stainless steel, anti-static, fire tested type.

2.2.3 The pumping unit is to be arranged to be connected to only one tank at a time. Pipes between the tanks and the pumping unit are to be of stainless steel or equivalent material, or flexible hoses of an approved type, fire-tested to an acceptable National Standard. Such pipes or hoses are to be protected from mechanical damage and be as short as possible. Where a flexible hose is used to connect the pumping unit to a tank, the hose connection is to be of the quick-disconnect, self-closing type.

2.2.4 Oil fuel bunkering system(s) for ship's propulsion and auxiliary engines are to be separate from the refuelling systems for aircraft. Provision is to be made for an emergency cross connection to enable:

(a) In an emergency, the supply of propulsion/auxiliary machinery oil fuel to aircraft/helicopters/vehicle refuelling systems.
(b) For operational reasons, the transfer and addition of aircraft fuel to the oil fuel storage system for the ship's propulsion/auxiliary engines.

The emergency cross connections are to incorporate an isolating valve on each system with a portable connection between them and be clearly marked and arranged to prevent inadvertent use.

2.2.5 Pumping units are to be capable of being controlled from the fuel station and from a position remote from the fuel station.

2.2.6 Pumping units shall incorporate a device to prevent over-pressurisation of the filling hose.

2.2.7 Arrangements for circulation of fuel through filter units, fuel metering and fuel sampling are to be provided. To allow circulation of fuel, each tank is to be provided with suitable high and low suction arrangements.

2.2.8 Filling arrangements for tanks are to be through closed piping systems with outlet ends configured to reduce turbulence and foaming of the fuel.

2.2.9 The locker housing equipment associated with fuel filling is to be well ventilated and drained.

2.2.10 Fuel piping systems are to be designed to limit the maximum flow rate to 7.0 m/s to reduce the possibility of the build up of static electricity.

2.2.11 Suitable filtration arrangements are to be provided to reduce the level of water and particulate contamination of the fuel to within the limits specified by the Owner/Operator.

2.2.12 Fuelling and defuelling stations are to be located away from, or sheltered from, radar and HF radio hazards. *See also* Pt 1, Ch 2,4.18.

2.2.13 Pipe systems designed for portable hose connections are to be provided with an isolating valve and blanking arrangement at each connection. Non-return valves are to be provided at connections where necessary to prevent back flow of fluids into systems and tanks where this could affect the integrity of the system or spaces.

2.2.14 All piping systems intended for fuel having a flash point less than 60ºC are to be located clear of accommodation spaces, escape routes, embarkation stations and ventilation openings and are not to pass through category A machinery spaces.

2.2.15 Means are to be provided for keeping deck spills away from accommodation and service areas. This may be accomplished by means of a 300 mm coaming extending from side to side. Special consideration will be given to the arrangements associated with stern loading.

2.2.16 Drip trays for collecting replenishment oil residues in pipelines and hoses are to be provided beneath pipe and hose connections in the manifold area.

2.3 Refuelling aircraft/helicopters

2.3.1 Service tanks for storing ready use fuel are to be provided with test facilities to determine fuel quality and stripping arrangements for removal of any water found. The tanks are to be provided with sloping bottoms to assist in stripping water.

2.3.2 Arrangements are to be provided for fuel to be passed through suitable filtration/water absorption equipment immediately prior to embarking fuel onto an aircraft. This equipment should be as near as practicable to the aircraft.

2.3.3 Refuelling and defuelling hoses are to be of an approved type. Hoses for refuelling are to include an automatic shut-off facility at the aircraft or vehicle end. A hose end pressure controller is also to be provided for fuelling hoses to prevent the possibility of the aircraft/helicopter fuel tanks being subject to excessive pressure.

2.3.4 Provision is to be made to earth the aircraft of static electricity before commencing and during any refuelling/defuelling procedure.

2.3.5 To allow through flushing, the pipe system to refuelling stations is to include shut off valves and a return pipe system to the storage or recovery tanks.

2.4 Defuelling

2.4.1 Arrangements are to be made to ensure that only fuel having a flash point equal to or greater than the flash point for which the ship has been designed and approved for is discharged into the ship's fuel storage system. Arrangements and equipment are to be provided to ensure that if defuelling of aircraft/helicopters carrying fuel having a flash point less than 60°C is required, the fuel flash point is increased to a figure above 60°C before discharge into the ship's storage system. Fuel from aircraft/helicopters may also be con-taminated and to provide segregation before discharge to the ship's storage system, a separate recovery tank for handling this fuel is to be provided. The capacity of the recovery tank is to be sufficient to safely handle the fuel from an aircraft/helicopter and is to be identified in the design statement required by 1.2.2.

2.4.2 Hoses used for defuelling are to comply with 2.3.3.

2.5 Fuel contamination

2.5.1 Materials and/or their surface treatment used for the storage and distribution of fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in fuel piping systems where they may come into contact with the fuel is not permitted. Copper-nickel materials are permissible but are to be limited to positions after the filtration/water absorption equipment required by 2.3.2.

2.5.2 The location and arrangement of air pipes for fuel tanks are to be such that in the event of a broken vent pipe, this does not directly lead to ingress of seawater or rain water.

■ *Section 3* Pump rooms

3.1 General

3.1.1 Where it is intended to install fuel transfer pumps for handling fuel with a flash point less than 60ºC in a separate compartment, the requirements of 3.1.2 to 3.1.5, 3.2 and 3.3 are to be complied with.

3.1.2 The pump rooms are to be totally enclosed and are to have no direct communication with machinery spaces.

3.1.3 Pump rooms are to be situated adjacent to the fuel storage tanks and are to be provided with ready means of access from the open deck.

3.1.4 Alarms and safety arrangements are to be provided as indicated in 3.1.5 and Table 4.3.1.

Table 4.3.1 Alarms

Item	Alarm	Note
Bulkhead gland temperature	High *See* Note 1	Any machinery item
Pump bearing and casing temperature	High *See* Note 1	Any machinery item
Bilge level	High	—
Hydrocarbon concentration	High *See* Note 2	>10% LEL

NOTES
1. The alarm signal is to trigger continuous visual and audible alarms in the pump room or the pump control station.
2. This alarm signal is to trigger a continuous audible and visual alarm in the pump room, pump control station and machinery control room.

3.1.5 A system for continuously monitoring the concentrations of hydrocarbon gases within the pump room is to be fitted. Monitoring points are to be located in positions where potentially dangerous concentrations may be readily detected. Gas analysing units with non-safe-type measuring equipment may be located outside cargo areas (e.g. in cargo control room, navigation bridge or engine room when mounted on the forward bulkhead) provided that:

(a) sampling lines do not pass through gas safe spaces, except where permitted by (e);
(b) the gas sampling pipes are fitted with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location, in the open atmosphere;
(c) bulkhead penetrations of sample pipes between safe and dangerous areas are of an approved type. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead in the safe area;
(d) the gas detection equipment including sampling piping, sampling pumps, solenoid valves and analysing units, are located in a fully enclosed steel cabinet, with a gasketed door, monitored by its own sampling point. At gas concentrations above 30 per cent LEL inside the steel cabinet, the entire gas-analysing unit is to be automatically shutdown; and
(e) where the cabinet cannot be arranged on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analysing units. The sample pipes are to be led by their shortest route.

3.1.6 Where the flash point of the fuel is not less than 60°C, the arrangements are to comply with the requirements applicable to machinery spaces, *see* Pt 1, Ch 2.

3.2 Pump room ventilation

3.2.1 Fuel pump rooms and other closed spaces which contain fuel handling equipment, and to which regular access is required during cargo handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

3.2.2 The ventilation system is to be capable of being operated from outside the compartment being ventilated and a notice to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes.

3.2.3 The ventilation systems are to be capable of 20 air changes per hour, based on the gross volume of the pump room or space.

3.2.4 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump room bilges, immediately above the transverse floor plates or bottom longitudinals. An emergency intake is also to be arranged in the ducting at a height of 2 m above the pump room lower platform and is to be provided with a damper capable of being opened or closed from the weather deck and lower platform level. An arrangement involving a specific ratio of areas of upper emergency and lower main ventilation openings, which can be shown to result in at least the required number of air changes through the lower inlets, can be accepted without the use of dampers. When the lower inlets are sealed off, owing to flooding of the bilges, then at least 75 per cent of the required number of air changes is to be obtainable through the upper inlets. Means are to be provided to ensure the free flow of gases through the lower platform to the duct intakes.

3.2.5 Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts, and ventilation intakes are to be so arranged as to minimise the possibility of re-cycling hazardous vapours from any ventilation discharge opening. Vent exits are to be arranged to discharge upwards.

3.2.6 The vent exits from pump rooms are to discharge at least 3 m above deck, and from the nearest air intakes or openings to accommodation and enclosed working spaces, and from possible sources of ignition.

3.2.7 The ventilation is to be interlocked to the lighting system (except emergency lighting) such that the pump room lighting may only come on when the ventilation is in operation. Failure of the ventilation system is not to cause the lighting to go out and failure of the lighting system is not to cause loss of the ventilation system.

3.3 Non-sparking fans for hazardous areas

3.3.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm whichever is the larger, subject also to compliance with 3.3.2(e). Generally, however, the air gap need be no more than 13 mm.

3.3.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) Impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity.
(b) Impellers and housings of non-ferrous metals.
(c) Impellers and housings of austenitic stainless steel.
(d) Impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller.
(e) Any combination of ferrous impellers and housings with not less than 13 mm tip clearance.
(f) Any combination of materials for the impeller and housing which are demonstrated as being spark proof by appropriate rubbing tests.

3.3.3 The following combinations of materials for impellers and housing are not considered spark proof and are not permitted:

(a) Impellers of an aluminium alloy or magnesium alloy and a ferrous housing, irrespective of tip clearance.
(b) Impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance.
(c) Any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by 3.3.2(c).

3.3.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e. materials having an electrical resistance between 5×10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

3.3.5 Type tests on the complete fan are to be carried out to the Surveyor's satisfaction.

3.3.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

3.3.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for piping systems installed in naval ships for the operation and functioning of equipment installed for purposes relating to the Ship Type.

1.1.2 The requirements in this Chapter cover piping and control systems necessary for ships that have Ship Type piping systems and equipment configured such that, in the event of a single failure or damage in any part of a piping system, the ship will continue to retain availability of essential services relating to the Ship Type.

1.1.3 The Naval Authority may impose requirements additional to those in this Chapter.

1.2 Scope

1.2.1 Ship Type piping systems included in this Chapter are:

(a) Chilled water systems used for:
   Weapons and electrical equipment cooling.
   Air conditioning systems.

(b) High pressure compressed air systems used for:
   Filling breathing air bottles used for diving and fire-fighting.
   Starting air for diesel engines and gas turbines.
   Machinery shaft brakes.
   Weapon handling and control.
   Supply to low pressure compressed air systems through reducing stations.

(c) Low pressure compressed air systems used for:
   Control systems for machinery and weapons.
   Air tools.
   Valve actuation.
   General supplies to seals, filters, sewage plant, etc.

(d) High pressure sea-water systems used for:
   Fire-fighting and boundary cooling.
   Pre-wetting.
   Bilge and dewatering eductors.
   Emergency cooling of machinery.
   Machinery space ventilation coolers in close-down operation.

(e) Hydraulic power actuating systems used for:
   Remote controlled equipment (doors, valves).
   Platform equipment (lifts, hoists).
   Machinery systems (stabilisers, hydraulic motors).

1.3 Plans and information

1.3.1 In addition to the information required by Ch 1,2.1.1, three copies of the plans and information stated in 1.3.2 to 1.3.7 are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **Design statement**. A design statement of each Ship Type piping system that details system capability and functionality under defined operating and emergency conditions. The design statement is to be agreed between the Designers and Owners/Operators.

1.3.3 **Systems**. Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems for each Ship Type piping system covered by this Chapter. The capacities of pumps and compressors are to be included. Capacity tables with condensing temperatures covering the operating range of the refrigeration compressors are also to be included. The tables are to be representative of the compressors operating at the design revolutions per minute with the nominated refrigerant.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the Ship Type system(s) installed and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Failure Mode and Effects Analysis (FMEA)**. For Ship Type piping systems with associated electrical power supplies and control systems, the FMEA report is to address the requirements in Section 5.

1.3.6 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in Section 3. In addition, any testing programme that may be necessary to prove the conclusions of the FMEA.

1.3.7 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The Manuals are to include the following information:

(a) Particulars and a description of each system.
(b) Operating instructions for all systems.
(c) Procedures for dealing with the situations identified in the FMEA report.

1.4 Use of alternative standards

1.4.1 Where it is proposed to use arrangements different from those required by this Chapter and the arrangements are in accordance with an applicable national/international standard, the use of such arrangements will be accepted by LR.

1.4.2 Where alternative design codes/standards are used, they are stated together with any assumptions made.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose.

2.1.2 Where applicable, the materials are to comply with the requirements of Ch 1,4.

2.1.3 Materials sensitive to heat, such as aluminium or plastics, are in general not to be used for Ship Type piping systems. Such materials are not in any event to be used in systems containing flammable liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments. *See* Chapter 1 for plastics pipes.

2.1.4 The selection of materials in piping systems is to recognize the following details:

(a) Fluids properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey and maintenance requirements.

See Ch 1,17 for guidance notes on metal pipes for water services.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes is to be in accordance with Chapter 1. Where refrigerant tubes are in tube bundles, special consideration will be given to the minimum thickness requirements recognising the inherent strength of tube bundles and the benefits of increased heat transfer properties of thin wall tubes.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment – Selection and installation

2.3.1 Air receivers and gas pressurised hydraulic accumulators are to be in accordance with Pt 8, Ch 2 or a recognized code and satisfy the Naval Authority's revalidation system for such items, where applicable. Materials used in the construction are to be manufactured and tested in accordance with Vol 1, Part 2.

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of Ch 1,12 to 15. Equipment used in Ship Type piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the *Lists of LR Type Approved Products* published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement. The selection of pipe connections in refrigeration systems is to minimize the possibility of refrigerant leaks and the use of flared fittings in such systems is to be avoided.

2.3.4 Suitable means for expansion are to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where these are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.3.7 Piping systems that may contain low temperature refrigerant are to be thermally insulated to an extent that will minimise condensation of moisture. Chilled water pipes are to be provided with insulation for system efficiency.

2.4 Valves – Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.4.4 The related discharge capacity of pressure relief valves is to be determined in accordance with a recognized standard or code.

■ *Section 3*
System arrangements

3.1 Piping systems

3.1.1 Piping systems are to be arranged so that supply of essential services relating to the Ship Type will continue to be available in the event of a single failure or damage of a system or item of equipment.

3.1.2 The design of piping systems is to minimise vulnerability and provide capability for maximising recovery of supply to users. Factors to be considered include; redundancy, separation, protection, accessibility for repair, means of bridging breaches, number of pumps, alternate power supplies and use of portable pumps where appropriate.

3.1.3 The design of piping systems is to recognize operational and manning philosophy for the vessel and is to be declared in the design statement required by 1.3.2.

3.1.4 The arrangement of equipment and systems is to ensure that failure or damage to a system will not cause immediate complete loss of the system. Systems are to be capable of accommodating progressive actions (manual and/or automatic) that will provide availability of supply to essential services for agreed periods of time in the event of action damage.

3.1.5 In the event of multiple failure or damage to a piping system, arrangements are to be provided to enable the system to be reconfigured to supply essential services.

3.1.6 Accessible means of isolation are to be provided to isolate damaged areas to ensure that maximum system capability remains available after damage to the piping system.

3.1.7 Piping systems are in general to be capable of providing support to, or substituting for, a similar but damaged system.

3.1.8 Where a piping system has failed or been damaged, any resulting hazards are to be minimised.

3.1.9 All equipment fitted in piping systems is to be readily accessible to facilitate maintenance and survey. For this purpose, valves or cocks are to be interposed between items of equipment and the inlet and outlet pipes in order that any item of equipment may be shut off for opening up and overhauling.

3.1.10 Filter elements fitted in piping systems are to be capable of being cleaned and or changed without interruption of fluid flow. Filter elements fitted in refrigerant circuits are also to be arranged to minimize refrigerant leakage to atmosphere when being cleaned and/or changed. The arrangements for cleaning and changing filter elements are to include means of isolation and recovery of ozone depleting substances before opening up.

3.1.11 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted that will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time. Where arrangements are such that a relief valve can be removed from a common discharge line shared with another relief valve, provision is to be made to blank off the open connection to the discharge line, without compromising the safety of the system.

3.1.12 Relief discharge is to be led to a safe place. Discharge piping is to be designed to preclude ingress of water, dirt or debris that may cause the equipment to malfunction. Any common discharge system for relief valves is to be arranged to ensure that with all the relief valves open, the back pressure of the discharge system will not exceed 10% of the valve set pressure.

3.1.13 Sea-water valves and fittings are to comply with Pt 7, Ch 2,2.5.

3.1.14 Piping system arrangements and associated equipment are to be capable of operating satisfactorily under the conditions shown in Table 2.4.1 in Pt 1, Ch 2.

3.2 Electrical power supplies

3.2.1 The electrical engineering arrangements are to comply with Pt 10, Ch 1.

3.2.2 The power supplies to electrical equipment in Ship Type systems are to be led from at least two independent sources that are capable of being connected by bus section switches.

3.2.3 In the event of the loss of one source of electrical supply, there is to be continuity of sufficient electrical power to supply the electrical equipment in Ship Type systems.

■ *Section 4*
Control arrangements

4.1 General

4.1.1 Equipment used in Ship Type piping systems is to be provided with local and remote control and monitoring arrangements.

4.1.2 The control, alarm and monitoring systems are to comply with Pt 9, Ch 1.

4.1.3 Where isolation of essential services is to be carried out whether automatically or manually, indication of the status of isolation is to be provided at each control station.

4.1.4 Indication of the operational status of running and standby equipment is to be provided for all Ship Type piping systems at each control station.

4.1.5 Alarms are to be provided for compartments containing equipment for operation of Ship Type piping systems in the event of:
(a) A fire.
(b) A high bilge alarm level in any compartment that could be flooded by ingress of sea water and situated below the damage control deck. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping out bilge wells, if applicable, are to comply with Pt 9, Ch 1,3.6.

4.1.6 Refrigeration compressors for chilled water systems are to be provided with the following instrumentation and automatic shutdowns:
(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure which is to operate at a pressure in excess of normal operating pressure but not greater than 0,9 of the maximum working pressure.
(g) Automatic shutdown in the event of a low suction pressure.

4.1.7 Refrigerant compressors greater than 25kW for chilled water systems are to be provided with the following instrumentation in addition to that required by 4.1.6:
(a) Indication of lubricating oil temperature.
(b) Indication of cooling water outlet temperature.
(c) Indication of suction and discharge temperatures.

4.1.8 Air compressors are to be provided with the following instrumentation and automatic shutdowns:
(a) Indication of discharge pressure and temperature.
(b) Indication of lubricating oil pressure and temperature.
(c) Indication of cooling water outlet temperature where applicable.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure.

4.1.9 Alarms are to be initiated in the event of the following fault conditions with the refrigerant compressors for cooling water systems and air compressors:
(a) High discharge pressure.
(b) Low suction pressure (cooling compressors only).
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

4.1.10 Chilled water systems are to be provided with the following alarms:
(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans associated with the operation of chilled water plant.
(d) High and low chilled water delivery temperatures.

4.1.11 All pumps are to be provided with an indication of discharge pressure, a low discharge pressure alarm and a motor shutdown alarm.

■ *Section 5*
Failure Mode and Effects Analysis

5.1 General

5.1.1 A FMEA is to be carried out in accordance with 5.1.2 to 5.1.7, for piping systems, electrical power supplies and control systems to demonstrate that a single failure or damage in these systems will not cause loss of all system capability.

5.1.2 The FMEA is to be carried out using the format presented in Table 5.5.1 or an equivalent format that addresses the same safety issues. Analysis in accordance with IEC 812, *Analysis for System Reliability – Procedures for Failure Mode and Effects Analysis*, would be acceptable.

5.1.3 The FMEA is to be organised in terms of items of equipment and function. The effects of item failures or damage at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be identified.

5.1.4 The FMEA is to:
(a) Identify the equipment or sub-system, mode of operation and the equipment.
(b) Identify potential failure modes and damage situations and their causes.
(c) Evaluate the effects on the system of each failure mode and damage situation.
(d) Identify measures for reducing the risks associated with each failure mode and damage situation.
(e) Identify trials and testing necessary to prove conclusions.

Table 5.5.1 Failure Mode and Effects Analysis

System				Element							
Item No.	Component description	Function	Mode of Operation	Failure Mode or Damage	Failure Cause	Failure Detection	Effect of Failure or Damage		Severity	Corrective Action	Remarks
							On Item	On System			

NOTE
The severity category is to be in accordance with the following:
(a) Catastrophic; (b) Hazardous; (c) Major; or (d) Minor.

5.1.5 At sub-system level it is acceptable, for the purpose of this Chapter, to consider failure or damage of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

5.1.6 Where FMEA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than the software code.

5.1.7 The FMEA is to establish that the system retains a level of operational capability as defined in the design statement required by 1.3.2, following failure or damage of pipework, an item of equipment or the loss of a compartment.

■ *Section 6*
Testing and trials

6.1 Testing

6.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*See* Pt 8, Ch 2,10 and Pt 7, Ch 1,16).

6.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

6.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

6.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety and where applicable, refrigerant detection systems.
(b) Tests simulating failure of selected components such as compressors, pumps and fans, to verify correct functioning of alarm and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control, monitoring and recording instrumentation for chilled water and associated refrigerant systems.

6.2 Type testing

6.2.1 Each type of pump and compressor unit is to be subjected to a type test that replicates the intended operating cycle/environment as far as practicable, e.g. still air conditions and high/low ambient air temperatures. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the units may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as may in service on board. During the whole test, no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the unit is to be opened out and inspected. Type tests may be waived for units that have been proven to be reliable in marine service or that have been previously type tested with satisfactory certification and testing evidence.

6.3 Trials

6.3.1 Trials are to be carried out to demonstrate the capability of systems to meet design statements. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

6.3.2 Where the FMEA report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure or damage situation.
(b) The effectiveness of automatic/manual isolation systems.
(c) The effectiveness of reconfiguration arrangements.
(d) The behaviour of any interlocks that may inhibit operation of other systems.

■ *Section 7* **Chilled water systems**

7.1 General

7.1.1 The requirements in this Section are additional to those contained in Sections 2 to 6 of this Chapter.

7.1.2 Chilled water systems are to produce and distribute treated demineralised chilled water throughout the ship to provide cooling to heat exchangers and other direct cooled equipment that may include air conditioning and weapons systems.

7.1.3 The refrigeration plant and chilled water system is to be designed to be capable of continuously extracting at least 115% of the maximum heat load duty when operating at the conditions stated in the design statement required by 1.3.2.

7.1.4 The demineralised water used in chilled water distribution systems is to be in accordance with the system designer's specification that typically would include the following limitations:

- Conductivity: <4,5 micromhs/cm^3
- Dissolved solids: Zero
- Alkalinity: pH 7,1
- Suspended solids: <2,5 ppm with particle size <250 microns

The specification for demineralised water is to be agreed by the Owner/Operator.

7.2 Refrigeration plant

7.2.1 Two or more independent refrigeration plants are to be provided and designed to be capable of extracting the heat load duty required by 7.1.3 when operating at the conditions stated in the design statement with any one plant out of action.

7.2.2 The refrigeration plants are to be located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render the other refrigeration plant(s) inoperative. In NS3 category ships the requirement for pumps to be located in separate zones will not be insisted on where agreed by the Owner/Operator and included in the design statement.

7.2.3 The compartments containing the refrigeration plants are to be provided with refrigerant gas detectors with audible and visual alarms.

7.2.4 The design of refrigeration systems is to be such that it permits maintenance and repair without unavoidable loss of refrigerant to the atmosphere. To minimise release of ozone depleting substances to the atmosphere, refrigerant recovery units are to be provided for evacuation of a system prior to maintenance.

7.2.5 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances that would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved. Where discharge of refrigerant gas to atmosphere is unavoidable arrangements are to be made to prevent discharge into ventilation systems.

7.2.6 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, a servo-operated valve will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

7.2.7 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valve is to be protected at all times by one of two pressure relief valves or one of two bursting discs, or one bursting disc or a pressure relief valve controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

7.2.8 Omission of one of the specified relief devices and changeover device, as required by 7.2.7, will be accepted where:

(a) vessels are of less than 300 litres internal gross volume; or
(b) vessels discharge into the low pressure side by means of a relief valve.

7.2.9 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

7.2.10 Where hermetically sealed compressor units or semi-hermetic compressors with the electric motor cooled by the circulating refrigerant are installed, the following arrangements are to be made:

(a) Each refrigeration system containing hermetically sealed compressor units or semi-hermetic compressors is to be independent of other refrigeration systems.

(b) All hermetic motor-compressors are to be fitted with a thermal cut-out device that protects the motor against overheating.

(c) Each refrigerant circuit is to be designed such that debris or contaminants from a motor failure, typically burn out of insulation, is contained and not distributed around the system.

7.3 Water system

7.3.1 Two or more chilled water pumps are to be provided and be of sufficient capacity to circulate chilled water at the flow rate and conditions stated in the design statement with any one pump out of action.

7.3.2 The chilled water pumps are to be located in separate compartments and zones such that loss of one compartment or zone, or failure in equipment will not render the chilled water system inoperative.

NOTE:
This does not preclude locating the chilled water pumps in the same compartment as the refrigeration plants mentioned in 7.2. Plants and their associated chilled water pumps are to be arranged such that the pumps can be cross-connected to other plants in the event of plant or pump failure. In NS3 category ships the requirement for pumps to be located in separate zones will not be insisted on where agreed by the Owner/Operator and included in the design statement.

7.3.3 The chilled water distribution system is to be of the constant flow type with a pneumatically pressurised expansion tank. Expansion tanks are to have a membrane fitted at the air/water interface to prevent ingress of air into the chilled water system.

7.3.4 Each user of chilled water is to be provided with means of isolation such that the distribution system can operate at the designed constant flow rate when the user is isolated.

7.3.5 The arrangement of chilled water distribution pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone.

7.3.6 Air vent and drain valves with adequate bleed off points for filling and in-service operational requirements are to be provided throughout the system at all high and low points.

7.3.7 Provision is to be made for filling and topping up the chilled water system. A means is also to be provided for connecting the system to a dry main for shore connection above the waterline. The shore connection is to be sized sufficient to enable supply of cooling water for the ship's requirement as declared in the design statement required by 1.3.2.

7.3.8 Provision is to be made to connect the chilled water distribution system to an alternative source of water supply for use in emergency/action damage conditions.

7.3.9 Seawater systems for refrigeration condensers are to be capable of being supplied from not less than two independent sources located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render loss of all seawater sources. In NS3 category ships the requirement for refrigeration condensers to be located in separate zones will not be insisted on where agreed by the Owner/Operator and included in the design statement.

7.3.10 The capacity of each source of seawater required by 7.3.9 is to be sufficient for the conditions stated in the design statement with any one source out of action.

■ *Section 8*
High pressure compressed air systems

8.1 General

8.1.1 The requirements of this Section are additional to those contained in Sections 2 to 6 of this Chapter.

8.1.2 High pressure (HP) compressed air systems are to produce and distribute compressed air throughout the ship to supply all systems and equipment where the air pressure requirement exceeds 7 bar. The systems are to include air compressors, oil/water separators, filter/dryers, distribution lines and air receivers. For the purpose of Naval Authority maintenance and safety regulatory requirements, HP air systems may be defined as those where the air pressure requirements exceed 25–40 bar and this is to be defined in the design statement required by 1.3.2.

8.1.3 The requirements for HP compressed air systems include the storage and distribution of compressed air with air pressures above 7 bar and are to be in accordance with the design statement required by 1.3.2. Additional compressed air systems may be installed for specific purposes such as for diesel engine starting (typically 25–30 bar systems) which are also to comply with the requirements of this Section and Pt 2, Ch 1,7 as applicable.

8.1.4 The design of HP compressed air systems is to be capable of providing continuous flow for all demands of equipment and system consumers, recognizing continuous and intermittent users. This includes any portable equipment that may be part of the ship's equipment.

8.1.5 The compressed air system users' quality (dryness, purity, etc.) requirements of compressed air are to be recognized in the selection of compressors, equipment, filters and dryers to be included in the system(s).

8.1.6 Arrangements for emergency depressurisation of HP compressed air to safe positions on open deck are to be provided. The controls for emergency depressurisation are to be located in readily accessible positions outside the space containing the HP air receivers.

8.2 Compressors

8.2.1 Two or more HP air compressors are to be provided of sufficient capacity to supply the total design demand of the system under defined requirements stated in the design statement required by 1.3.2 with any one compressor out of action.

8.2.2 The compressors are to be located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render the other compressor(s) inoperative.

8.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation of pressure with the outlet valve closed will not exceed 10 per cent of the maximum working pressure of the compressor. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

8.2.4 Each compressor is to be provided with an alarm for failure of the lubricating oil supply that will initiate an automatic shutdown.

8.2.5 Adequate air supply arrangements via a steel trunk are to be provided to the compartment where the compressor is located and where a vessel is provided with an NBCD citadel, arrangements are to ensure that there is adequate air supply to the compressor in closedown. Care is to be taken to ensure that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour.

8.2.6 Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe from each compressor.

8.2.7 Drain valves for removing accumulations of oil and water are to be fitted on compressors and their associated coolers, separators and filters.

8.3 Air receivers

8.3.1 The HP air system and associated air receivers are to be configured to provide sufficient capacity to supply HP compressed air to users when any section of the distribution line is isolated due to failure or damage.

8.3.2 The configuration of the HP air system and associated air receivers for each essential user of HP compressed air is to be arranged to provide without replenishment, sufficient air to operate systems and equipment at an agreed capability level for an agreed period of time. In general, at least two air receivers of approximately equal capacity are to be provided for each essential user or group of users.

8.3.3 All air receivers are to be provided with mounting and fittings required by Pt 8, Ch 2,9.

8.3.4 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

8.3.5 Air receivers used for pressurising magazine water spray systems are to be capable of being isolated from the HP compressed air distribution lines to prevent automatic replenishment of the receiver after use.

8.4 Distribution system

8.4.1 The arrangement of HP compressed air pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone. Isolating valves are to be fitted in each branch from the main distribution system to permit isolation of any damaged branches.

8.4.2 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

8.4.3 Reducing valves/stations for users of reduced pressure air are to be provided throughout the ship. Pipelines that are situated on the low pressure side of reducing valves/stations, and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure. In-line filters are to be fitted at each reducing valve/station on the reduced pressure side.

8.4.4 A means is to be provided for connecting the HP compressed air system to a shore connection.

■ *Section 9* Low pressure compressed air systems

9.1 General

9.1.1 The requirements of this Section are additional to those contained in Sections 2 to 6 of this Chapter.

9.1.2 Low pressure (LP) compressed air systems are to produce and distribute oil and moisture free cool compressed air throughout the ship to supply all systems and equipment where the air pressure requirements are 7 bar and below. The systems are to include air compressors, oil/water separators, filter/dryers, distribution lines and air receivers. For the purpose of Naval Authority maintenance and safety regulatory requirements, LP air systems may be defined as those where the air pressure requirements are 25–40 bar and below and this is to be defined in the design statement required by 1.3.2.

9.1.3 The design of LP compressed air systems is to be capable of providing continuous flow for all demands of equipment and system consumers recognizing continuous and intermittent users. This includes any portable equipment that may be part of the ship's equipment. Compressed air systems used for specific purposes such as for diesel engine or gas turbine starting are also to comply with the requirements of this Section and Pt 2, Ch 1,7 and Pt 2, Ch 2,6 as applicable.

9.1.4 The quality (dryness, purity etc) requirements of compressed air is to be recognized in the selection of compressors, equipment, filters and dryers to be included in the system(s).

9.1.5 Configuration arrangements of LP compressed air systems may consist of:

(a) Dedicated LP air compressors and LP air receivers with a distribution system for LP users; or
(b) Dedicated LP air compressors feeding directly into a distribution system for LP air users; or
(c) Supply from the HP air system to dedicated air pressure reducing valves/stations and air receivers feeding into a distribution system for LP users.

Where the arrangements are configured as described in (a) and (b), arrangements are to be made for connections to the LP air system via reducing valves/stations from the HP compressed air system.

9.2 Compressors and reducing valves/stations

9.2.1 Where LP air is not derived from the HP air system, two or more LP air compressors are to be provided of sufficient capacity to supply the total design demand of the system with any one compressor out of action.

9.2.2 With the exception of the need to trunk in an air supply for NBCD design in 8.2.5, the requirements of 8.2.2 to 8.2.7 are also to be complied for LP air compressors.

9.2.3 Where the design of the LP compressed air system requires the use of dedicated LP air compressors feeding directly into a distribution system of LP air users, the compressors are to be capable of continuous running with arrangements for ensuring that compressor output matches demand.

9.2.4 Where LP air is derived only from a HP compressed air system, two or more reducing valves/stations are to be provided of sufficient capacity to supply the total demand of the LP air system with any one reducing valve/station out of action.

9.3 Air receivers

9.3.1 The LP air system and associated air receivers are to be configured to provide sufficient capacity to supply LP compressed air to users when the distribution line is isolated due to failure or damage.

9.3.2 The configuration of the LP air system and associated air receivers for each essential user of LP compressed air is to be arranged to provide, without replenishment, sufficient air to operate systems and equipment at an agreed capability level for an agreed period of time. In general, at least two air receivers of approximately equal capacity are to be provided for each essential user or group of users.

9.3.3 All air receivers are to be provided with mounting and fittings required by Pt 8, Ch 2,9.

9.3.4 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

9.4 Distribution system

9.4.1 The arrangement of LP compressed air pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone. Isolating valves are to be fitted in each branch from the distribution system(s) to permit isolation of any damaged branches.

9.4.2 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

9.4.3 Reducing valves/stations for users of reduced pressure air are to be provided throughout the ship. Pipelines that are situated on the low pressure side of reducing valves/stations, and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure. In-line filters are to be fitted at each reducing valve/station on the reduced pressure side.

9.4.4 A means is to be provided for connecting the LP compressed air system to a shore connection.

■ *Section 10* High pressure sea-water systems

10.1 General

10.1.1 The requirements in this Section are additional to those contained in Sections 2 to 6 of this Chapter.

10.1.2 High pressure sea-water (HPSW) systems are to continuously supply and distribute sea-water at a pressure of generally not less than 7 bar throughout the ship to provide water for fire-fighting, magazine spraying, pre-wetting, bilge and dewatering eductors and emergency cooling. *See* 10.2.6 for water pressure requirements.

10.1.3 The pumping and delivery capacities and pressures from the HPSW are to be sufficient to support damage control and fire-fighting policy, procedures and techniques, including pre-wet requirements that are to be declared in the design statement required by 1.3.2.

10.1.4 Ship-side valves and fittings are to comply with the requirements of Ch 2,2.5 as applicable.

10.2 Pump units

10.2.1 Three or more HPSW pumps are to be provided of sufficient capacity to supply the total pumping capacity defined in 10.2.3 with any one pump out of action. At least one of the pumps is to be capable of supplying HPSW in a dead ship condition.

10.2.2 The pumps are to be located in separate compartments and zones such that the loss of one compartment or zone or failure in equipment will not render the other pumps inoperative.

10.2.3 The total pumping capacity of the HPSW pumps with one pump out of action shall provide for the greatest of the following:

(a) The amount required for pre-wetting.
(b) The amount required for a fire in the largest machinery space using the largest fixed spray system plus 40 m^3/hr boundary cooling from hoses.
(c) The amount required for a major fire outside the machinery spaces using 100 m^3/hr boundary cooling for each fire. The minimum number of fires to be considered are as follows:
    (i) Displacement at design draught of under 4,000 tonnes – one fire
    (ii) Between 4,000 and 10,000 tonnes – two fires
    (iii) Between 10,000 and 20,000 tonnes – three fires
    (iv) Over 20,000 tonnes – four fires

    Reference is also to be made to the design statement required by 1.3.2 where the number of fires to be considered may also reference amongst other items, the type of ship, number of personnel on board and number of fire zones.
(d) The largest single magazine or ammunition transfer space spray requirement plus 40 m^3/hr boundary cooling.
(e) The hangar spray requirement in the largest area contained by a fire curtain.
(f) A flight deck fire requiring one third of the total foam branch pipes fitted in multi-aircraft landing (multi-spot) ships or two foam branch pipes in single aircraft landing (single spot) ships.

If the factor determining the total pumping capacity is (b), then any pumps located in the space are to be added to the overall number of pumps required.

10.2.4 The capacity of each pump is to be not less than that required to supply water for the eductor capacities referred to in Ch 2,6.3.

10.2.5 The sea suctions to HPSW pumps are to be provided with an air elimination arrangement to ensure that the running and standby pumps do not become air-locked.

10.2.6 HPSW pumps are to be arranged to operate continuously with automatic and switched means of starting of standby pumps on sea-water demand. Automatic starting of standby pumps may be achieved by sensing when the system pressure falls below a pre-set level. The continuous and minimum supply pressures in the HPSW distribution system are to be in accordance with the design statement required by 1.3.2.

10.2.7 HPSW pumps are to be provided with high temperature alarms for components that may become overheated when the pump is running in low or no flow demand conditions.

10.2.8 Where HPSW pumps can develop a pressure greater than the design pressure of the system, they are to be provided with pressure relief/control devices on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

10.2.9 Strainers capable of being cleaned without interruption of water flow to the pumps are to be provided in the suction pipes.

10.3 Distribution system

10.3.1 The arrangement of the HPSW system is to ensure continuous availability of supply in the event of the loss of any compartment or zone. Isolating valves are to be fitted in each branch from the main distribution system to permit isolation of any damaged branches.

10.3.2 HPSW should be supplied throughout the ship by means of a ring main system. In multi-spot ships fitted with a between deck hangar, a second ring main should be provided. These ring mains are to be cross-connected but may share the same pumps. Alternative arrangements to a ring main system will be considered where a vulnerability assessment has demonstrated that continuous availability of HPSW can be ensured whilst satisfying the system arrangement requirements of this Chapter.

10.3.3 Ring mains are to extend over the middle two thirds of the length of the ship, one half to port and the other to the starboard side. Each ring main is to be cross-connected across the ship in separate fire zones recognizing any vulnerability requirements stated by the Owner. The main is to be extended forward and aft of the ring main by a single line of piping at the centre.

10.3.4 The HPSW system is to be capable of being isolated into separate sections by local and remote controlled valves at the fire zone boundaries. In addition, isolating valves are to be fitted at the following locations:

(a) At the riser from the pump to the ring main.
(b) In the ring main each side of the pump riser junction.
(c) At each cross-over connection junction to the ring main.
(d) Where the ring main penetrates a watertight bulkhead.
(e) In the ring main each side of the branch to the magazine spray system.

10.3.5 Where the HPSW system is to be used for fire-fighting purposes, the supplies are to be led through vertical distribution lines directly from the horizontal ring main to the upper deck levels.

10.3.6 Shore and ship to ship connections to the HPSW ring main are to be provided port and starboard on the weatherdeck – one pair forward, the other aft, i.e. a total of four connections. For **NS3** category ships with a breadth not exceeding 10 m, a single connection forward and a single connection aft will be acceptable.

■ *Section 11* Hydraulic power actuating systems

11.1 General

11.1.1 The requirements of this Section are additional to those contained in Sections 2 to 6 of this Chapter. The requirements do not apply to steering systems that are covered in Pt 6, Ch 1.

11.1.2 The arrangements for storage, distribution and utilisation of hydraulic and other flammable oils employed under pressure in power transmission systems, control and actuating systems and heating systems in locations where means of ignition are present are to comply with the provisions of Ch 3, 2.8.4, 2.8.5, 2.8.6, 4.2, 4.3, 4.5, 4.11 and 4.16 where applicable.

11.1.3 Hydraulic power actuating systems are to deliver hydraulic fluid under pressure for actuation of hydraulically driven machinery and for operation of remote controlled equipment.

11.1.4 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions and conform to the Naval Authority's safety policy where applicable.

11.1.5 Materials used for all parts of hydraulic seals are to be compatible with working fluid at the appropriate working temperature and pressure.

11.1.6 Hydraulic power actuating systems for hydraulically driven machinery and for the operation of remotely controlled equipment are to be independent of each other.

11.1.7 Piping systems for flammable hydraulic fluids are to be installed to avoid fluid spray or leakage onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to LR. Pipes are to be led in well-lit and readily visible positions.

11.2 Hydraulic fluid storage

11.2.1 Tanks and reservoirs for service and the storage of hydraulic fluids are to be made of steel and suitable for the maximum head of fluid to which the tanks may be subjected. In general, tanks are to have a minimum plate thickness of 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

11.2.2 The storage capacity for hydraulic fluid(s) is to be sufficient to recharge the largest system on board plus normal usage during a typical mission. Storage capacity is to be sufficient for each type of hydraulic fluid used on the ship. Storage capability sufficient to handle the full capacity of the largest hydraulic system on board is also to be provided for dirty hydraulic fluids.

11.2.3 Tanks and reservoirs are to be provided with two connections at diagonally opposite corners, one top and one bottom to permit the contents to be circulated through portable flushing equipment.

11.2.4 The capacity of hydraulic fluid reservoirs at normal working level is to ensure a residence time for the fluid of not less than three minutes.

11.2.5 A vertical baffle plate is to be fitted dividing each reservoir into two compartments interconnected at the top of the baffle. Return fluid, drains, etc., are to be made to one side of the baffle whilst pump suctions are to be taken from the other side.

11.2.6 All tanks and reservoirs are to be provided with approved means of hydraulic fluid level indication.

11.2.7 All tanks and reservoirs are to be provided with approved means of sampling the contents and a means of access for cleaning.

11.3 Pump units

11.3.1 Two or more hydraulic pumps are to be provided for each power actuating system, the pumps are to be of sufficient capacity to supply the system under defined operational requirements stated in the design statement required by 1.3.2 with any one pump out of action.

11.3.2 All hydraulic pumps are to be provided with relief valves. Each relief valve is to be in close circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

11.3.3 The power supply to all independently driven pumps used for pumping flammable fluids is to be capable of being stopped from a position outside the space. It shall be possible to activate the stop from this position in the event of a fire occurring in the space containing the pumps, in addition to any stop facilities provided in the space.

11.3.4 Where pump units are provided with accumulators, a shut-off valve is to be provided between the pressure line and the accumulator with a bleed valve fitted between the shut-off valve and the accumulator.

11.3.5 Where accumulators are provided with gas pressurisation, isolating valves are to be fitted in the gas lines at each accumulator. A relief valve is to be fitted in the gas supply line to limit prevent the accumulator being pressurised above its maximum working pressure.

11.4 Supply systems and arrangements

11.4.1 Supply systems to hydraulic power actuating systems are to be as short as practicable.

11.4.2 Where hydraulic pipes penetrate watertight or fire zone bulkheads, isolating valves are to be provided.

11.4.3 The use of flexible hoses is to be restricted to positions where it is necessary to accommodate relative movement between items of equipment and fixed pipework.

11.4.4 Where emergency fire valves are hydraulically operated, accumulators are to be provided in the common supply lines to facilitate rapid operation of the valve actuators in the event of fire.

11.4.5 Provision is to be made for emergency hand pump or hand wheel operation of hydraulic systems.

11.4.6 Where a hydraulic securing is applied, the system is to be capable of being mechanically locked in the closed position so that, in the event of hydraulic system failure, the securing arrangements will remain locked.

11.4.7 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

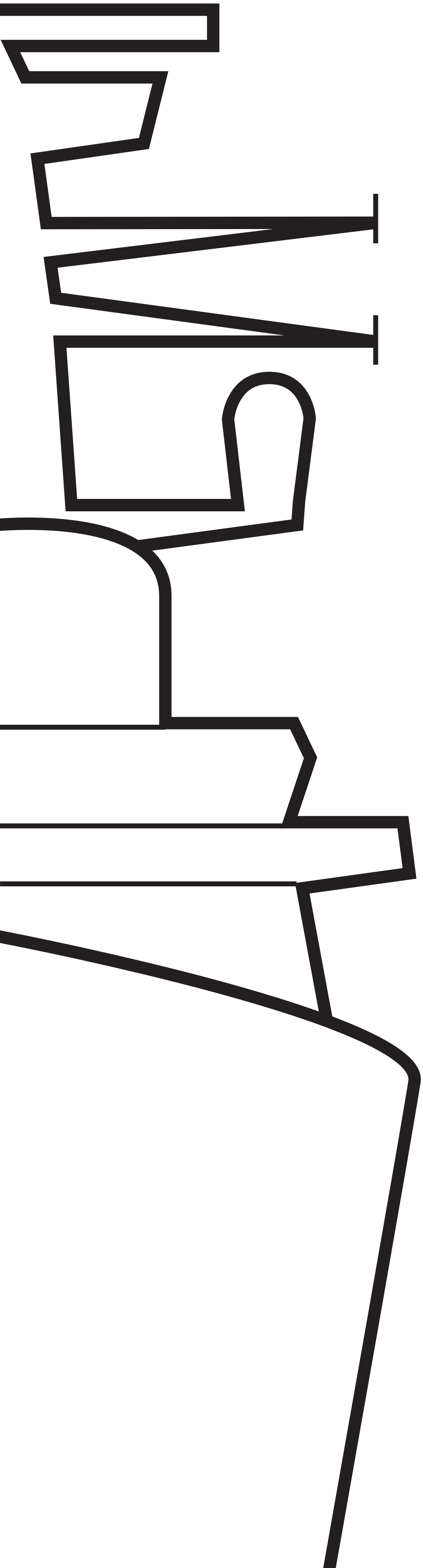
11.4.8 Hydraulic circuits for securing and locking of bow, inner, stern or shell doors are to be arranged such that they are physically unable to be affected by operation of other hydraulic circuits when securing and locking devices are in the closed position. For requirements relating to hydraulic steering gear arrangements *see* Pt 6, Ch 1,5.3

11.4.9 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

11.5 Cooling arrangements

11.5.1 Cooling arrangements for hydraulic fluids are to be provided where the operating temperature of the fluid may exceed the maximum design temperature limitations of the fluid or equipment in the system as defined in the design statement required by 1.3.2.

11.5.2 Where the provision of cooling arrangements is necessary to maintain hydraulic fluid temperatures, not less than two means of cooling are to be provided and configured such as to provide cooling with one means out of action.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 8*

Pressure plant

January 2005

Lloyd's Register

Chapter Contents

Volume 2, Part 8

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■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.
(b) Heating of pressurised hot water above 120°C.
(c) Heating of pressurised thermal liquid.

The formulae in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Vol 1, Pt 2, Ch 5.

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas, are to comply with the appropriate requirements of this Chapter.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 8, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* 2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The following values are to be regarded as the minimum:

(a) For fired steam boilers, *T*, is to be taken as not less than 250ºC.
(b) For steam heated generators, secondary drums of double evaporation boilers, steam receivers and pressure parts of fired pressure vessels, not heated by hot gases and adequately protected by insulation, *T*, is to be taken as the maximum temperature of the internal fluid.
(c) For pressure parts heated by hot gases, *T*, is to be taken as not less than 25ºC in excess of the maximum temperature of the internal fluid.
(d) For boiler, superheater, reheater and economiser tubes, *T*, is to be taken as indicated in 7.1.2.
(e) For combustion chambers of the type used in horizontal wet-back boilers, *T*, is to be taken as not less than 50ºC in excess of the maximum temperature of the internal fluid.
(f) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat transfer, *T*, is to be taken as not less than 90ºC in excess of the maximum temperature of the internal fluid.

1.4.3 In general any parts of boiler drums or headers not protected by tubes, and exposed to radiation from the fire or to the impact of hot gases, are to be protected by a shield of good refractory material or by other approved means.

1.4.4 Drums and headers of thickness greater than 35 mm are not to be exposed to combustion gases having an anticipated temperature in excess of 650ºC unless they are efficiently cooled by closely arranged tubes.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels with fusion welded seams are graded as Class 1 if they comply with the following conditions:

(a) For pressure parts of fired steam boilers, fired thermal liquid heaters and exhaust gas heated shell type steam boilers where the design pressure exceeds 3,4 bar.
(b) For pressure parts of steam heated steam generators and separate steam receivers where the design pressure exceeds 11,3 bar, or where the pressure, in bar, multiplied by the internal diameter of the shell, in mm, exceeds 14 420.

1.5.2 For Rule purposes, pressure vessels with fusion welded seams, used for the production or storage of steam, the heating of pressurised hot water above 120ºC or the heating of pressurised thermal liquid not included in Class 1 are graded as Class 2/1 and 2/2.

1.5.3 Pressure vessels which are constructed in accordance with Class 2/1 or Class 2/2 standards (as indicated above) will, if manufactured in accordance with requirements of a superior class, be approved with the scantlings appropriate to that class.

1.5.4 Pressure vessels which have only circumferential fusion welded seams, will be considered as seamless with no class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent class as determined by 1.5.1 and 1.5.2.

1.5.5 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

1.5.6 Heat treatment, non-destructive examinations and routine tests, where required, for the three classes of fusion welded pressure vessels are indicated in Table 1.1.1. Details are given in Pt 1, Ch 3.

1.6 Plans

1.6.1 Plans of boilers, superheaters and economisers are to be submitted in triplicate for consideration. When plans of water tube boilers are submitted for approval, particulars of the safety valves and their disposition on boilers and superheaters, together with the estimated pressure drop through the superheaters, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

1.6.2 Plans, in triplicate, showing full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

Table 1.1.1 Heat treatment, non–destructive examination and testing requirements

Class	Radiographic examination	Heat treatment	Routine weld tests	Hydraulic test
1	Required *see* Pt 1, Ch3	*see* Pt 1, Ch3	Required	Required
2/1	Spot required *see* Pt 1, Ch3	*see* Pt 1, Ch3	Required	Required
2/2	—	*see* Pt 1, Ch3	Required	Required

1.7 Materials

1.7.1 Materials used in the construction are to be manufactured and tested in accordance with the requirements of Vol 1, Part 2.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:
(a) For seamless, Class 1, Class 2/1 and Class 2/2 fusion welded pressure vessels:
340 to 520 N/mm^2.
(b) For boiler furnaces, combustion chambers and flanged plates:
400 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2 and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 The specified minimum tensile strength of boiler and superheater tubes is to be within the following general limits:
(a) Carbon and carbon-manganese steels:
320 to 460 N/mm^2.
(b) Low alloy steels:
400 to 500 N/mm^2.

1.7.5 Where it is proposed to use materials other than those specified in Vol 1, Part 2, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.7.6 Where a fusion welded pressure vessel is to be made of alloy steel, and approval of the scantlings is required on the basis of the high temperature properties of the material, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where
E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with Vol 1, Part 2, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 8, where applicable. Fusion welded pressure parts are to be made in accordance with Pt 1, Ch 3.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75

1.9.2 The longitudinal and circumferential joints for all classes of pressure vessels for the purposes of this Chapter are to be butt joints. For typical acceptable methods of attaching dished ends, *see* Fig. 1.14.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in Sections 2 to 8, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may be required to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:
(a) impact loads, including rapidly fluctuating pressures;
(b) weight of the vessel and normal contents under operating and test conditions;
(c) superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping;
(d) reactions of supporting lugs, rings, saddles or other types of supports; or
(e) the effect of temperature gradients on maximum stress.

■ *Section 2* Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, t, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma J - 0{,}5p} + 0{,}75 \text{ mm}$$

where t, p, R_i and σ are defined in 1.2,

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 or 2.2, whichever applies. In the case of seamless shells clear of tube holes or other openings, J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 Irrespective of the thickness determined by the above formula, t is to be not less than:

(a) 6,0 mm for cylindrical shell plates.

(b) For tube plates, such thickness as will give a minimum parallel seat of 9,5 mm, or such greater width as may be necessary to ensure tube tightness, *see* 14.6.

2.2 Efficiency of ligaments between tube holes

2.2.1 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis, the efficiency, J, of the ligaments is to be determined as in 2.2.2, 2.2.3 and 2.2.4.

2.2.2 **Regular drilling**. Where the distance between adjacent tube holes is constant, *see* Fig. 1.2.1,

$$J = \frac{s - d}{s}$$

where

d = the mean effective diameter of the tube holes, in mm, after allowing for any serrations, counter-boring or recessing, or the compensating effect of the tube stub. *See* 2.3 and 2.4.

s = pitch of tube holes, in mm.

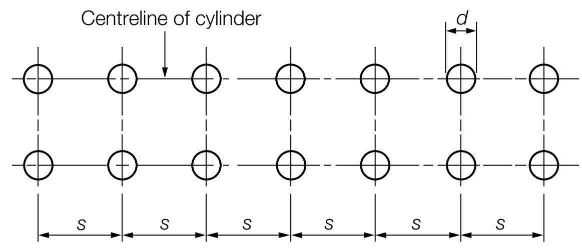


Fig. 1.2.1 Regular drilling

2.2.3 **Irregular drilling**. Where the distance between centres of adjacent tube holes is not constant, *see* Fig. 1.2.2:

$$J = \frac{s_1 + s_2 - 2d}{s_1 + s_2}$$

where d is as defined in 2.2.2

s_1 = the shorter of any two adjacent pitches, in mm

s_2 = the longer of any two adjacent pitches, in mm.

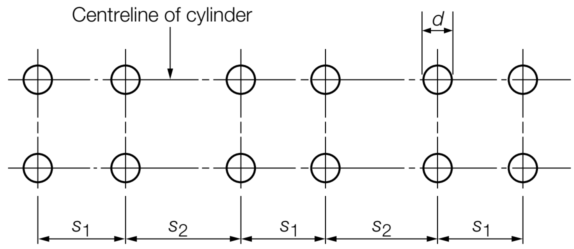


Fig. 1.2.2 Irregular drilling

2.2.4 When applying the formula in 2.2.3, the double pitch ($s_1 + s_2$) chosen is to be that which makes J, a minimum, and in no case is s_2 to be taken as greater than twice s_1.

2.2.5 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by the formula in 2.2.2 and 2.2.3 is less than one-half of the ligament efficiency on the longitudinal axis, J in 2.1 is to be taken as twice the circumferential efficiency.

2.2.6 Where tube holes are drilled in a cylindrical shell along a diagonal line with respect to the longitudinal axis, the efficiency, J, of the ligaments is to be determined as in 2.2.7 to 2.2.10.

2.2.7 For spacing of tube holes on a diagonal line as shown in Fig. 1.2.3, or in a regular saw-tooth pattern as shown in Fig. 1.2.4, J is to be determined from the formula in 2.2.8, where a and b, as shown in Figs. 1.2.3 and 1.2.4, are measured, in mm, on the median line of the plate, and d, is as defined in 2.2.2.

2.2.8 For tube holes on a diagonal line:

$$J = \frac{2}{A + B + \sqrt{(A - B)^2 + 4C^2}}$$

where

$$A = \frac{\cos^2\alpha + 1}{2\left(1 - \dfrac{d\cos\alpha}{a}\right)}$$

$$B = 0{,}5\left(1 - \frac{d\cos\alpha}{a}\right)(\sin^2\alpha + 1)$$

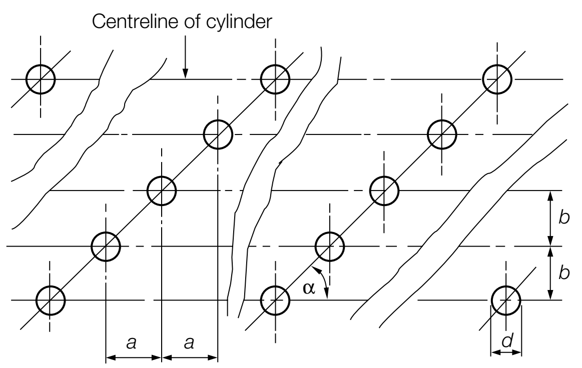


Fig. 1.2.3 Spacing of holes on a diagonal line

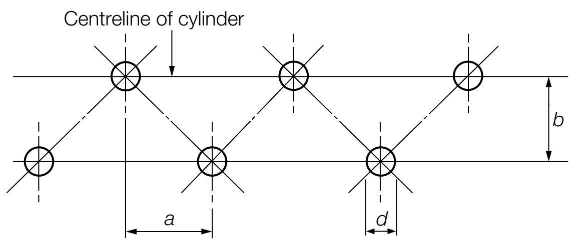


Fig. 1.2.4 Regular saw-tooth pattern of holes

$$C = \frac{\sin\alpha\cos\alpha}{2\left(1 - \frac{d\cos\alpha}{a}\right)}$$

$$\cos\alpha = \frac{1}{\sqrt{1 + \frac{b^2}{a^2}}}$$

$$\sin\alpha = \frac{1}{\sqrt{1 + \frac{a^2}{b^2}}}$$

α = angle between centreline of cylinder and centreline of diagonal holes.

2.2.9 For regularly staggered spacing of tube holes as shown in Fig. 1.2.5, the smallest value of the efficiency, *J*, of all ligaments (longitudinal, circumferential and diagonal) is to be used where *a* and *b* as shown in Fig. 1.2.5 are measured, in mm, on the median line of the plate, and *d* is as defined in 2.2.2.

2.2.10 For irregularly spaced tube holes whose centres do not lie on a straight line, the formula in 2.2.3 is to apply, except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using the formula in 2.2.2, the same efficiency as would be obtained using the formula in 2.2.8 for the diagonal ligament in question.

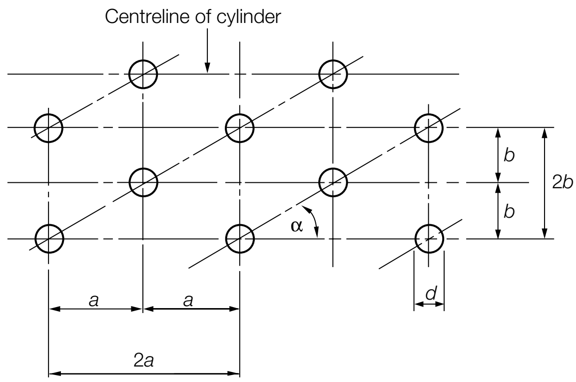


Fig. 1.2.5 Regular staggering of holes

2.3 Compensating effect of tube stubs

2.3.1 Where a drum or header is drilled for tube stubs fitted by strength welding, either in line or in staggered formation, the effective diameter of holes is to be taken as:

$$d_e = d_a - \frac{A}{t}$$

where

d_e = the equivalent diameter of the hole, in mm
d_a = the actual diameter of the hole, in mm
t = the thickness of the shell, in mm
A = the compensating area provided by each tube stub and its welding fillets, in mm^2.

2.3.2 The compensating area, *A*, is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows, *see* Figs. 1.2.7 and 1.2.8:

- The cross-sectional area of the stub, in excess of that required by 7.1 for the minimum tube thickness, from the interior surface of the shell up to a distance, *b*, from the outer surface of the shell;
- plus the cross-sectional area of the stub projecting inside the shell within a distance, *b*, from the inner surface of the shell;
- plus the cross-sectional area of the welding fillets inside and outside the shell;

where

$b = \sqrt{d_a t_b}$
t_b = actual thickness of tube stub, in mm.

2.3.3 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the ratio:

$$\frac{\text{allowable stress of stub at design metal temperature}}{\text{allowable stress of shell at design metal tempera-}}$$

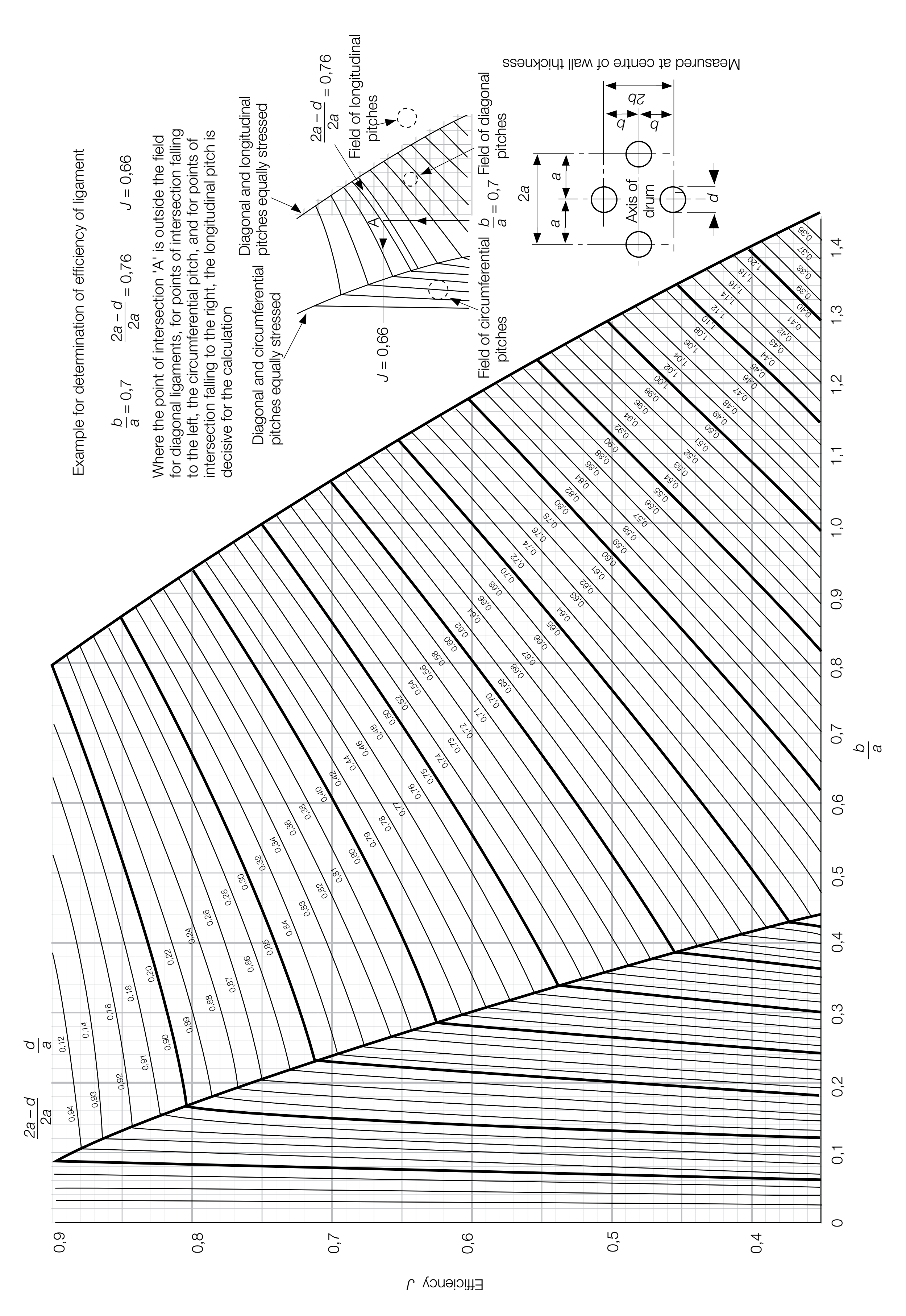
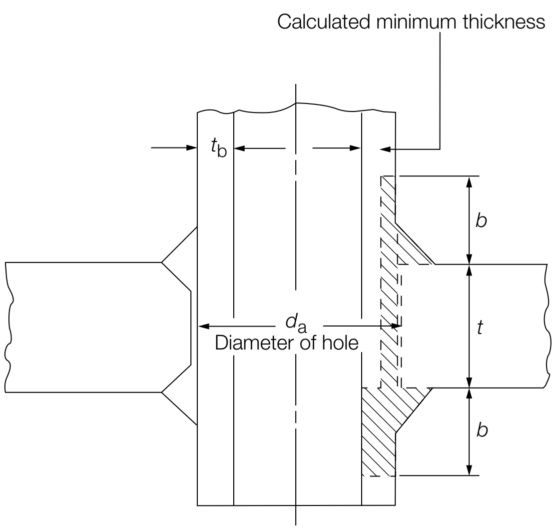
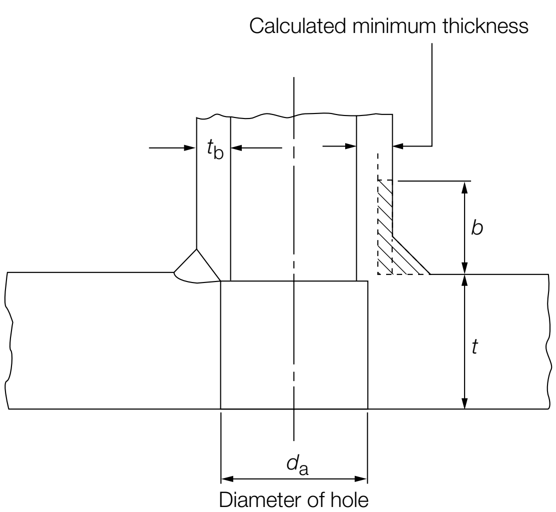


Fig. 1.2.6 Efficiency of ligaments between holes



The area shown hatched is half the area *A*

Fig. 1.2.7
Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.



The area shown hatched is half the area *A*

Fig. 1.2.8
Compensation of welded tube stubs
The calculated minimum thickness is to satisfy 7.1.

2.4 Unreinforced openings

2.4.1 Openings in a definite pattern, such as tube holes, may be designed in accordance with the Rules for ligaments in 2.2, provided that the diameter of the largest hole in the group does not exceed that permitted by 2.4.2.

2.4.2 The maximum diameter, *d*, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\,[D_o\,t\,(1 - K)]^{1/3} \quad \text{in mm}$$

The value of *K* to be used is calculated from the following formula:

$$K = \frac{pD_o}{18{,}2\sigma t} \text{ but is not to be taken as greater than 0,99}$$

where p, D_o and σ are as defined in 1.2
t = actual thickness of shell, in mm.

2.4.3 For elliptical or oval holes, *d*, for the purposes of 2.4.2, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.4.4 No unreinforced opening is to exceed 200 mm in diameter.

2.4.5 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$d + 1{,}1\sqrt{Dt}$ with a minimum $5d$

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)
D = mean diameter of shell
t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.
Where two holes are offset on a diagonal line, the diagonal efficiency from Fig. 1.2.6 may be used to derive an equivalent longitudinal centre distance for the purposes of this paragraph.

2.5 Reinforced openings

2.5.1 Openings larger than those permitted by 2.4 are to be compensated in accordance with Fig. 1.2.9(a) or (b). The following symbols are used in Fig. 1.2.9(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm
t_d = thickness calculated in accordance with 7.1 without corrosion allowance, in mm
t_a = actual thickness of shell plate without corrosion allowance, in mm
t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm
t_r = thickness of added reinforcement, in mm
D_i = internal diameter of cylindrical shell, in mm
d_o = diameter of hole in shell, in mm
L = width of added reinforcement not exceeding D, in mm
C = $\sqrt{d_o\,t_b}$ in mm
D = $\sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm
σ = shell plate allowable stress, N/mm^2
σ_p = standpipe allowable stress, N/mm^2
σ_r = added reinforcement allowable stress, N/mm^2
σ_w = weld metal allowable stress, N/mm^2

NOTE
σ_p, σ_r and σ_w are not to be taken as greater than σ.

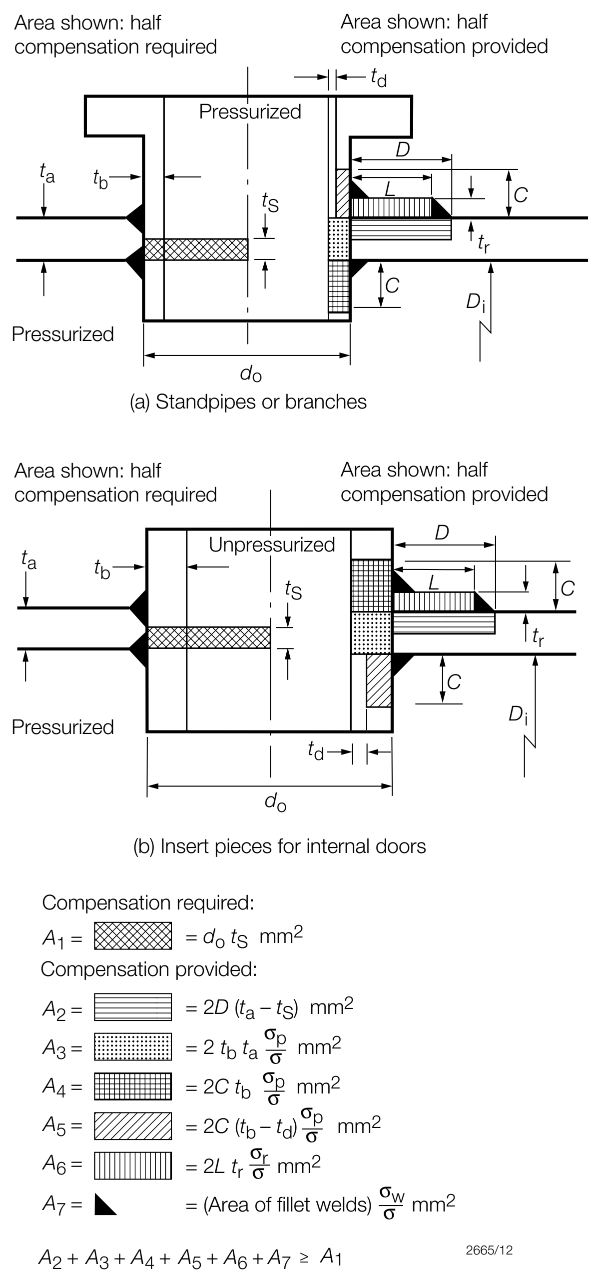


Fig. 1.2.9
Compensation for welded standpipes or branches in cylindrical shells

2.5.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for do in 2.5.1.

2.5.3 Compensation is to be distributed equally on either side of the centreline of the opening.

2.5.4 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

■ *Section 3*
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness of a spherical shell is to be determined by the following formula:

$$t = \frac{pR_i}{20\sigma J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Openings in spherical shells requiring compensation are to comply, in general, with 2.5, using the calculated and actual thicknesses of the spherical shell as applicable.

■ *Section 4*
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_o K}{20\sigma J} + 0{,}75 \quad \text{mm}$$

where t, p, D_o, σ and J are as defined in 1.2
K = a shape factor, *see* 4.2 and Fig. 1.4.1.

4.1.2 For semi-ellipsoidal ends:
the external height, $H \geq 0{,}18D_o$

where
D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:
the internal radius, $R_i \leq D_o$
the internal knuckle radius, $r_i \geq 0{,}1D_o$
the internal knuckle radius, $r_i \geq 3t$
the external height, $H \geq 0{,}18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)(R_o + 0{,}5D_o - 2r_o)}$$

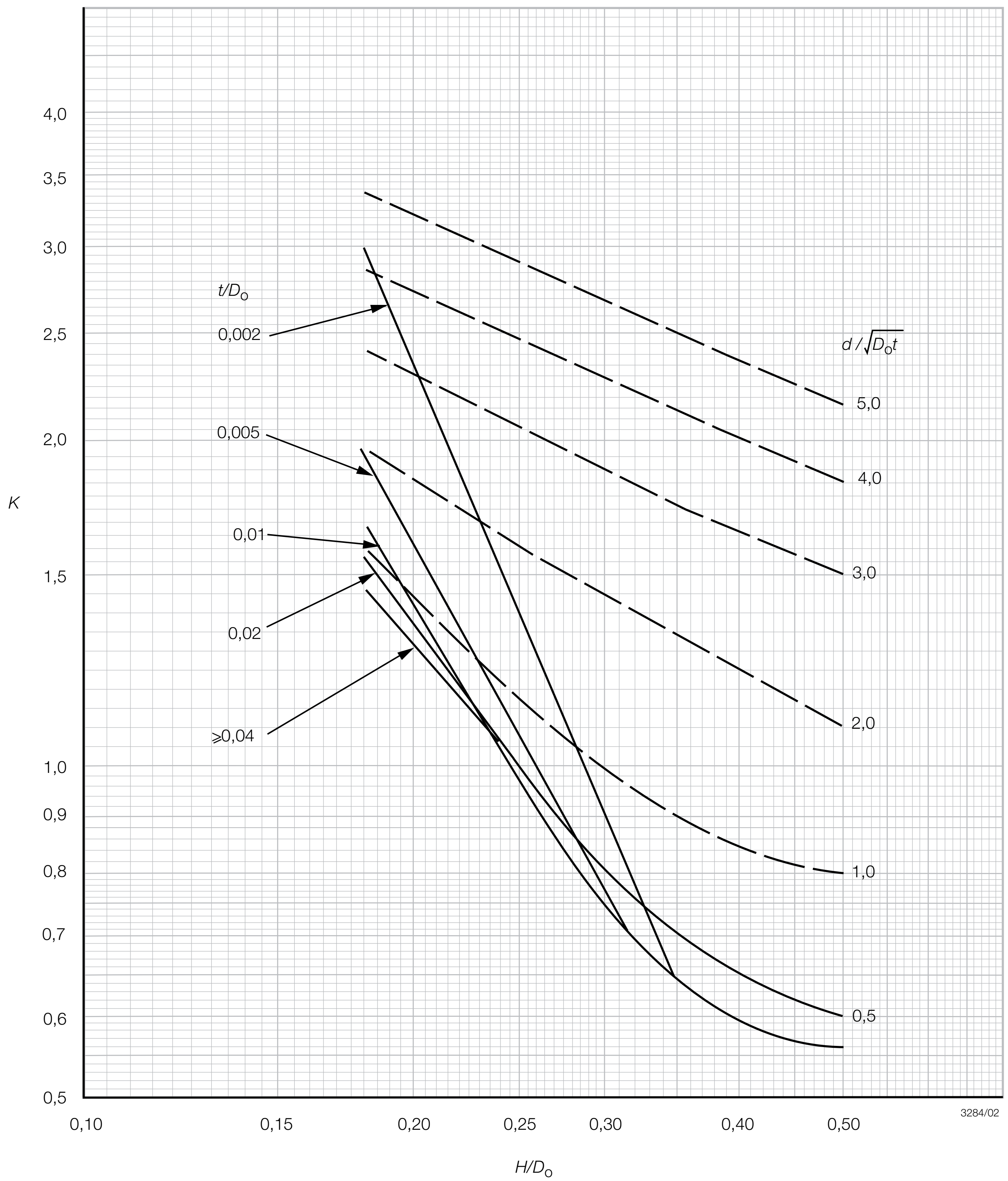


Fig. 1.4.1 Shape factor

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{pR_i}{20\sigma J - 0{,}5p} + 0{,}75 \quad \text{mm}$$

where t, p, R_i, σ and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crownsection for a distance not less than $0{,}5\sqrt{R_i\,t}$ mm, before reducing to the crown thickness permitted by 4.1.4, where

t = the required thickness from 4.1.1.

4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 1.4.2.

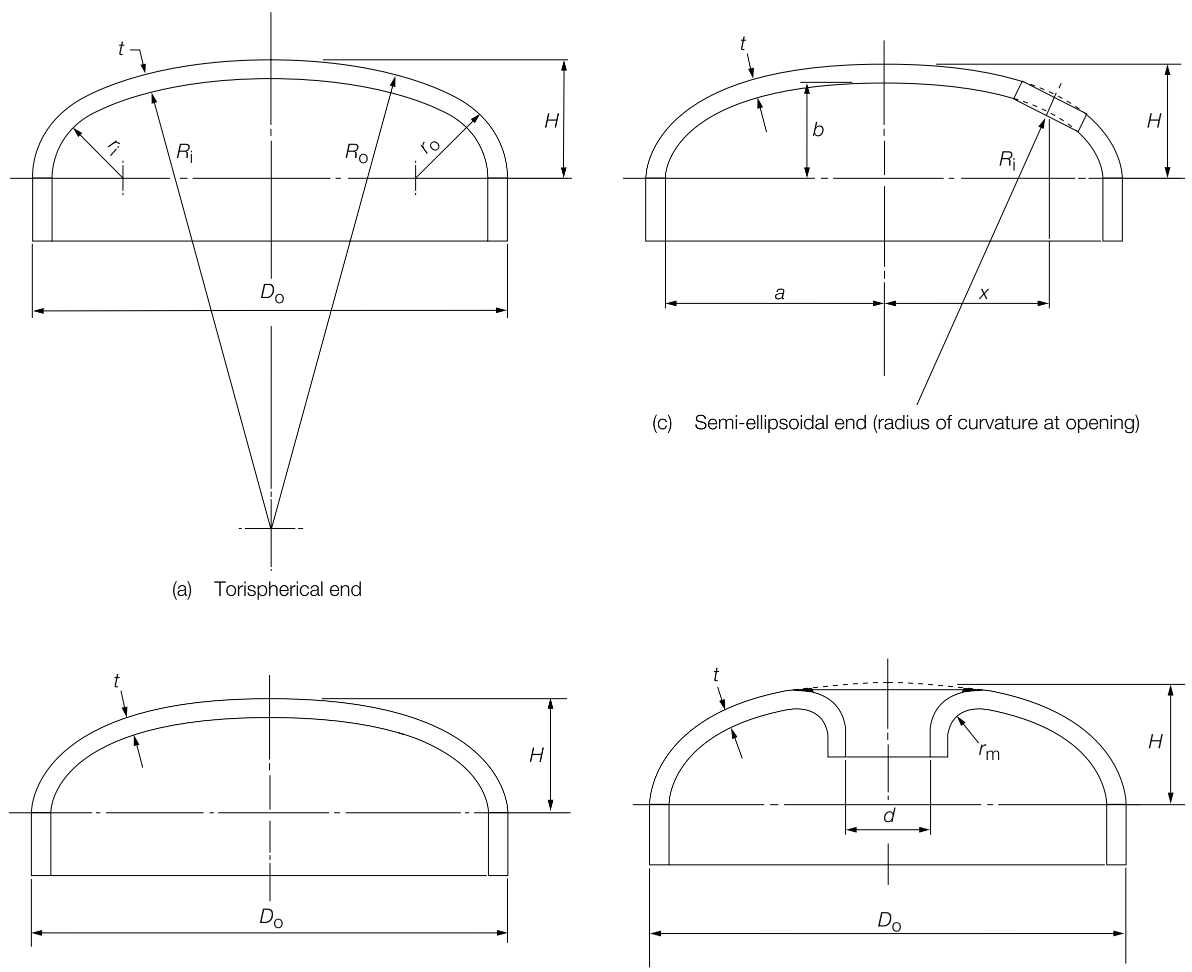
4.1.7 The minimum thickness of the head, t, is to be not less than 6,0 mm.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.8, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 1.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{H}{D_o}$, as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.



(a) Torispherical end

(b) Semi-ellipsoidal end

(c) Semi-ellipsoidal end (radius of curvature at opening)

(d) End with manhole (semi-ellipsoidal or torispherical)

Fig. 1.4.2 Typical dished ends

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in Fig. 1.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_o\, t}}$ and trial calculation is necessary to select the correct curve, where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)
t = minimum thickness, after dishing, in mm
D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7.$$

4.3.4 From Fig. 1.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o\, t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o\, t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 1.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 1.4.3.

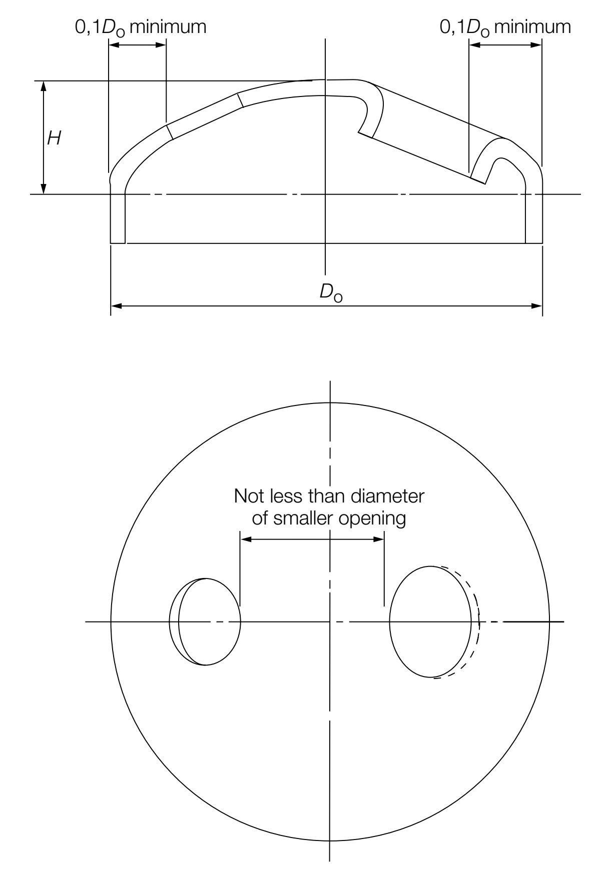


Fig. 1.4.3 Opening in dished ends

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, see Fig. 1.4.4. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i\, t}$ or $0{,}5d_o$ whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o\, t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or
R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{[a^4 - x^2\,(a^2 - b^2)]^{3/2}}{a^4\, b}$$

where a, b and x are shown in Fig. 1.4.2(c)

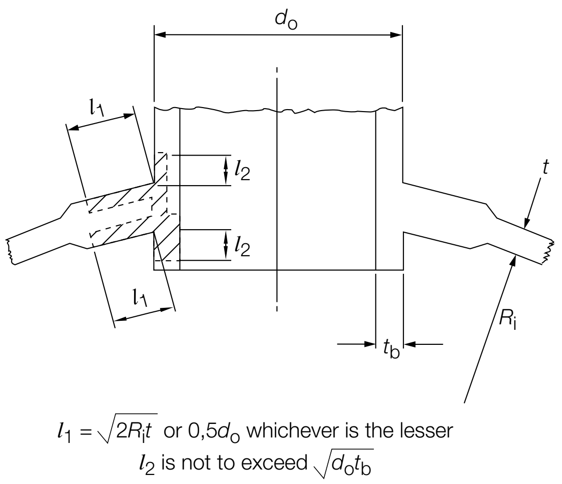


Fig. 1.4.4 Limits of reinforcement

d_o = external diameter of ring or standpipe, in mm
l_1 and l_2 are shown in Fig. 1.4.4
t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, *K*, for a dished end having a reinforced opening can be read from Fig. 1.4.1 using the value obtained from:

$$\frac{d_o - \frac{A}{t}}{\sqrt{D_o\, t}} \text{ instead of from } \frac{d}{\sqrt{D_o\, t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 1.4.4.

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 1.4.4 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2
- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2 and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 7.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, *A*, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise the requirements of 4.6 are to be applied.

■ *Section 5*
Conical ends subject to internal pressure

5.1 General

5.1.1 Conical ends and conical reducing sections, as shown in Fig. 1.5.1, are to be designed in accordance with the equations given in 5.2.

5.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 1.5.1. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

5.1.3 Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

5.2 Minimum thickness

5.2.1 The minimum thickness, *t*, of cylinder, knuckle and conical section at the junction and within the distance, *L*, from the junction is to be determined by the following formula:

$$t = \frac{p\, D_o\, K}{20\sigma J} + 0{,}75 \text{ mm}$$

where *t*, *p*, σ and *J* are as defined in 1.2

K = a factor, taking into account the stress in the knuckle, *see* Table 1.5.1.

D_o = outside diameter, in mm, of the conical section or end, *see* Fig. 1.5.1.

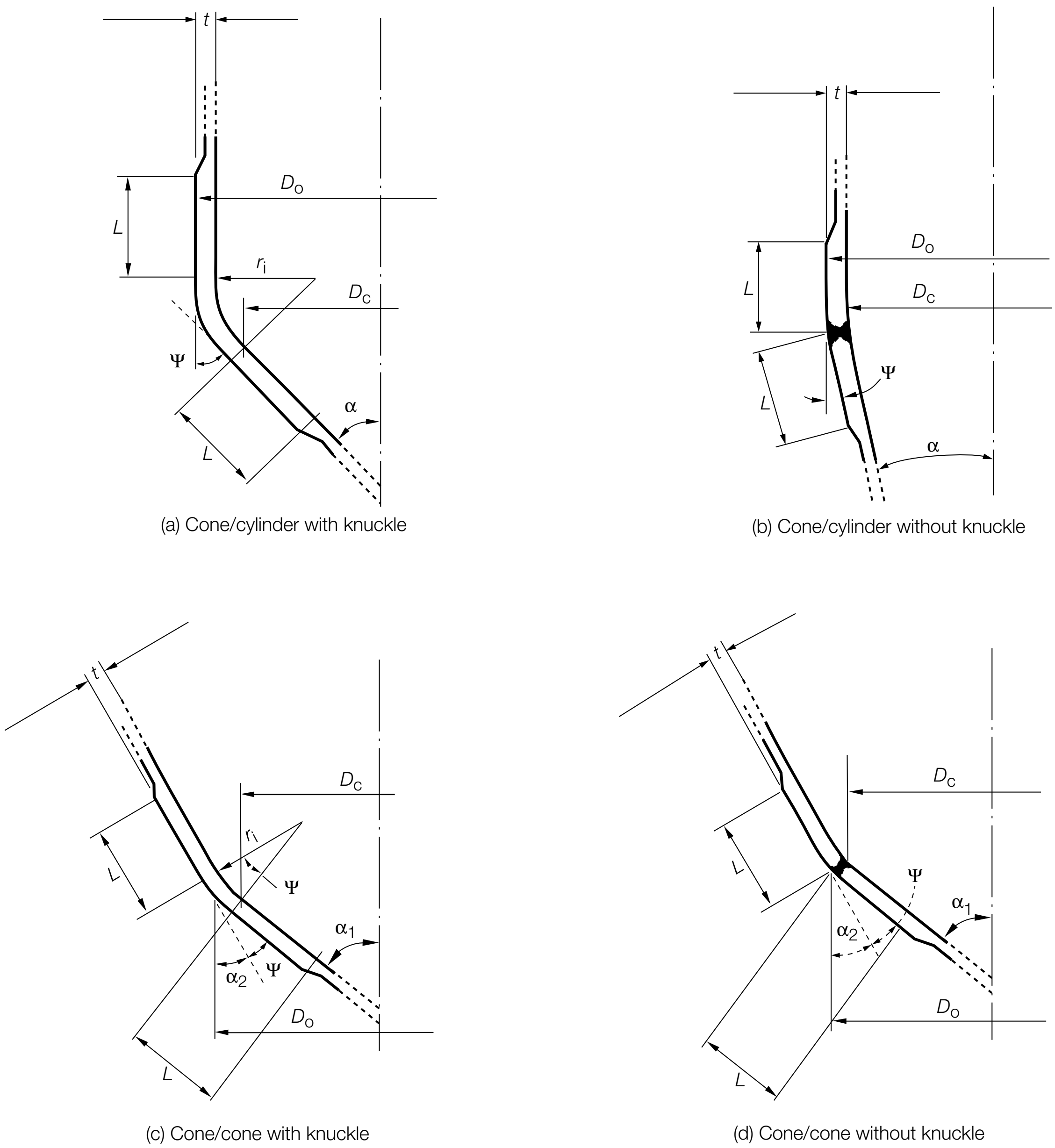


Fig. 1.5.1

Table 1.5.1 Values of *K* as a function of ψ and r_i / D_o

ψ	Values of K for r_i/D_o ratios of 0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55

5.2.2 If the distance of a circumferential seam from the knuckle or junction is not to be less than L, then J is to be taken as 1,0; otherwise J is to be taken as the weld joint factor appropriate to the circumferential seam,

where

L = distance, in mm, from the knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 1.5.1

$$= 0{,}5 \sqrt{\frac{D_o\, t}{\cos \psi}}$$

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition.

ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 1.5.1.

5.2.3 The minimum thickness, t, of those parts of conical sections not less than a distance, L, from the junction with a cylinder or other conical section is to be determined by the following formula:

$$t = \frac{p\, D_c}{(20\sigma J - p)} \; \frac{1}{\cos \alpha} + 0{,}75 \text{ mm}$$

where

D_c = inside diameter, in mm of conical section or end at the position under consideration, *see* Fig. 1.5.1

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 1.5.1.

5.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 6
Standpipes and branches

6.1 Minimum thickness

6.1.1 The minimum wall thickness of standpipes and branches is to be not less than that determined by 7.1 increased by the addition of a corrosion allowance of 0,75 mm, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is to be not less than:

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

This thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\, t} \text{ mm}$$

where t and D_o are as defined in 1.2.

6.1.2 For boilers having a working pressure exceeding 50 bar and safety valves of full lift or full bore type, the thickness of the branch pipe carrying the superheater or drum safety valves is to be not less than:

$$t = \frac{1}{\sigma}\left[1{,}7d + \frac{DWK}{1{,}3d^2}\right]\text{mm}$$

where t and σ are as defined in 1.2

d = inside diameter of branch, in mm

D = inside diameter of safety valve discharge, in mm

K = 2 for superheater safety valves

= 1 for drum safety valves

W = total valve throughput, in kg/h.

6.1.3 The offset from the centreline of the waste steam pipe to the centreline of the safety valve is not to exceed four times the outside diameter of the safety valve discharge pipe. The waste steam pipe system is to be supported and arrangements made for expansion such that no direct loading is imposed on the safety valve chests and the effects of vibration are to be minimised.

6.1.4 The pipe or header which carries the superheater safety valve is to be suitably thickened but is to be not less than the thickness required for the branch for a distance of $\sqrt{D_2\, t}$ on either side of the opening

where

t = thickness required for the branch

D_2 = inside diameter of the pipe or header.

6.1.5 Except as required by 6.1.4, in no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

6.1.6 Where a standpipe or branch is connected by screwing, the thickness is to be measured at the root of the thread.

6.1.7 For boiler, superheater or economiser tubes, the minimum thickness of the drum or the header connection or tube stub is to be calculated as part of the tube in accordance with 7.1.

Section 7
Boiler tubes subject to internal pressure

7.1 Minimum thickness

7.1.1 The minimum wall thickness of straight tubes subject to internal pressure is to be determined by the following formula:

$$t = \frac{p\, D_o}{20\sigma + p} \text{ mm}$$

where t, p, D_o and σ are as defined in 1.2.

NOTES

1. Provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see* 7.2.
2. Thickness is in no case to be less than the minimum shown in Table 1.7.1.

Table 1.7.1 Minimum thickness of tubes

Nominal outside diameter of tube in mm	Minimum thickness in mm
≤ 38	1,75
> 38 ≤ 50	2,16
> 50 ≤ 70	2,40
> 70 ≤ 75	2,67
> 75 ≤ 95	3,05
> 95 ≤ 100	3,28
> 100 ≤ 125	35,0

7.1.2 The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature, which will be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and LR, the metal temperature used to decide the value of, σ for these tubes is to be determined as follows:

(a) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature, plus 25°C for tubes mainly subject to convection heat, or plus 50°C for tubes mainly subject to radiant heat.

(b) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered, plus 35°C for tubes mainly subject to convection heat. For tubes mainly subject to radiant heat the calculation temperature is generally to be taken as not less than the steam temperature expected in the part being considered, plus 50°C, but the actual metal temperature expected is to be stated when submitting plans.

(c) The calculation temperature for economiser tubes is to be taken as not less than 35°C in excess of the maximum temperature of the internal fluid.

7.1.3 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes.

7.2 Tube bending

7.2.1 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is to be not less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

7.2.2 Tube bending, and subsequent heat treatment, where necessary, is to be carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

CROSS-REFERENCES

For details of manholes, sight holes and doors, *see* 14.1.
For details of tube holes and fitting of tubes, *see* 14.6.

■ *Section 8* **Headers**

8.1 Circular section headers

8.1.1 The minimum thickness of circular section headers is to be calculated in accordance with the formula for cylindrical shells in 2.1.

8.2 Rectangular section headers

8.2.1 The thickness of the flat walls of rectangular section headers is to be determined at the centre of the sides, at all the lines of holes and at the corners. The minimum required shall be the greatest thickness determined by the following formula:

$$t = \frac{pn}{20\sigma J} + \sqrt{\frac{0{,}4Yp}{\sigma J_1}} + 0{,}75 \text{ mm}$$

where t, p and σ are as defined in 1.2

n = one half of the internal width of the wall perpendicular to that under consideration, in mm, *see* Fig. 1.8.1

Y = a coefficient determined in accordance with 8.2.2. In all cases if the value of Y is negative, the sign is to be ignored.

J = ligament efficiency for membrane stresses determined in accordance with 8.2.3

J_1 = ligament efficiency for bending stresses determined in accordance with 8.2.3.

8.2.2 The coefficient Y for use in 8.2.1 is to be determined as follows:

(a) at the centre of the side with internal width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{1}{2} m^2$$

where

m = one half of the internal width of the wall under consideration, in mm, *see* Fig. 1.8.1(b)

(b) at a line of holes parallel to the longitudinal axis of the header on the wall of width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2 + b^2}{2}$$

where

b = distance from the centre of the holes to the centre line of the wall, in mm, *see* Fig. 1.8.1(a)

(c) to check the effect of the off-set on a staggered hole arrangement where the holes are positioned equidistant from the centre line of the wall:

$$Y = \cos\alpha \left\{ \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2}{2} \right\}$$

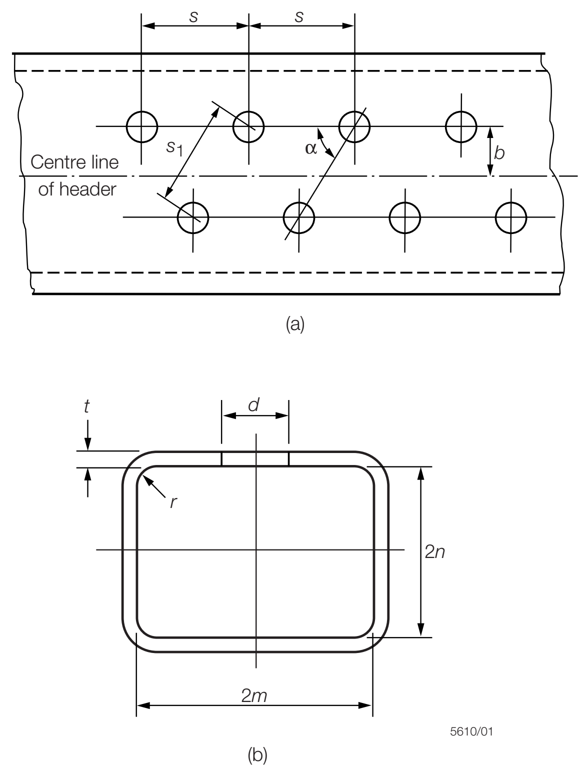


Fig. 1.8.1 Rectangular section headers

where

α = the angle subtended by the diagonal ligament on the longitudinal ligament, *see* Fig.1.8.1(a)

(d) at the corners:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right)$$

8.2.3 The ligament efficiencies J and J_1 are to be determined as follows:

(a) for a line of holes parallel to the longitudinal axis of the header:

$$J = \frac{s - d}{s}$$

(b) for the diagonals:

$$J = \frac{s_1 - d}{s_1}$$

(c) for a line of holes parallel to the longitudinal axis of the header:

$$J_1 = \frac{s - d}{s} \quad \text{when } d < 0{,}6m$$

or

$$J_1 = \frac{s - 0{,}6m}{s} \quad \text{when } d \geq 0{,}6m$$

(d) for the diagonals:

$$J_1 = \frac{s_1 - d}{s_1} \quad \text{when } d < 0{,}6m$$

or

$$J_1 = \frac{s_1 - 0{,}6m}{s_1} \quad \text{when } d \geq 0{,}6m$$

where

d = diameter of the hole in the header, in mm

m, s and s_1, in mm, are as shown in Fig. 1.8.1.

8.2.4 In the case of elliptical holes the value of d to be used in the equations for J and J_1 is to be the inside dimension of the hole measured parallel to the longitudinal axis of the header. For evaluating the two limiting values of d in the equations for d_1, the value of d is to be the inside dimension of the hole measured perpendicular to the longitudinal axis of the header.

8.2.5 The internal corner radius, r, is to be not less than one third of the mean of the nominal thicknesses of the two sides, but in no case to be less than 6,5 mm.

8.3 Toroidal furnace headers

8.3.1 The minimum thickness of a toroidal header forming the lower end of a waterwall furnace, and supporting the weight of the boiler and water, is to be determined by the following formula:

$$t = A + \sqrt{A^2 + \frac{4M}{JS\,\sigma}} + 0{,}75 \text{ mm}$$

where

$$A = \frac{pr}{30\,J\sigma} \text{ mm}$$

t, p and σ are as defined in 1.2

d_e = equivalent diameter of the tube hole in accordance with 2.3

r = inside radius of toroid circular cross-section, in mm, *see* Fig. 1.8.2

J = ligament efficiency of tube holes around toroid

$$= \frac{S - d_e}{S}$$

S = pitch of tubes around the toroid, in mm

$$M = \frac{W\,r}{3} - \frac{p\,d^2\,r}{40} \text{ Nmm}$$

where

W = imposed loading on each water wall tube due to the weight of the boiler and water, in N

d = minimum diameter of the tube hole in the toroid, in mm

The calculation is to be performed at design pressure using the allowable stress at saturation temperature, and also at zero pressure using the allowable stress at 100°C.

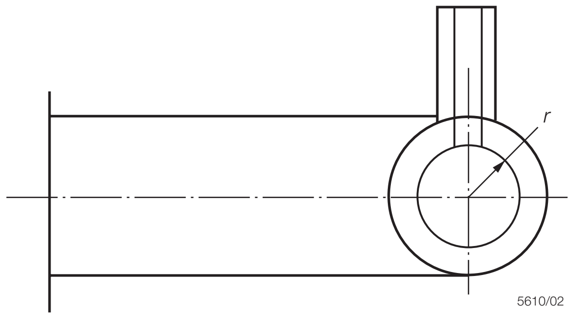


Fig. 1.8.2 Toroidal furnace headers

8.4 Header ends

8.4.1 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

8.4.2 Where sufficient experience of previous satisfactory service of headers with integrally forged ends cannot be shown, the suitability of a proposed form of end is to be proved in accordance with the provisions of 1.10.

8.4.3 Ends attached by welding are to be designed as follows:

Dished ends: these are to be in accordance with 4.1.

Flat ends: the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{p\,C}{\sigma}} + 0{,}75 \text{ mm}$$

where p and σ are as defined in 1.2.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular header or least width between walls of rectangular header, in mm

C = a constant depending on method of end attachment, *see* Fig. 1.8.3.

For end plates welded as shown in Fig. 1.8.3(a):

C = 0,019 for circular headers
= 0,032 for rectangular headers.

For end plates welded as shown in Fig. 1.8.3(b) and (c):

C = 0,028 circular headers
= 0,040 for rectangular headers.

8.4.4 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

8.4.5 Openings in flat plates are to be compensated in accordance with Fig. 1.2.9(a) or (b), with the value of A_1 the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4}\, t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 8.4.3 or 9.1.6, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

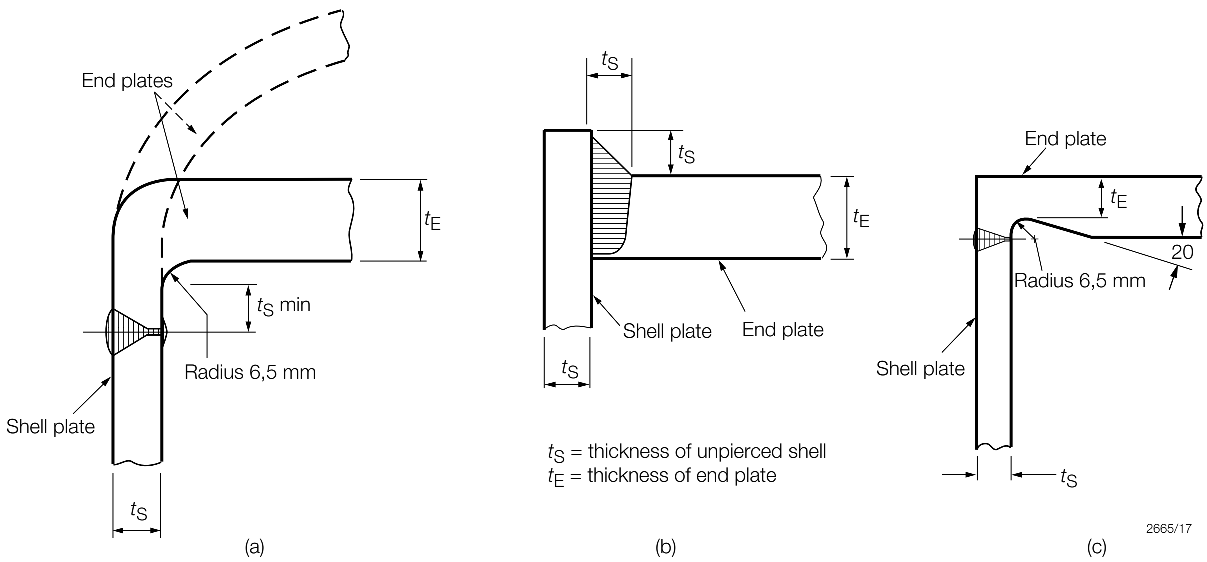


Fig. 1.8.3 Typical methods of attachment of header end closures

Section 9
Flat surfaces and flat tube plates

9.1 Stayed flat surfaces

9.1.1 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is to be not less than 1,75 times the thickness of the plate, with a minimum of 38 mm.

9.1.2 Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm.

9.1.3 Where unflanged flat plates are connected to the shell by welding, typical methods of attachment are shown in Fig. 1.9.1. Similar forms of attachment may be used where unflanged combustion chamber or firebox plates are connected to the wrapper plate by welding.

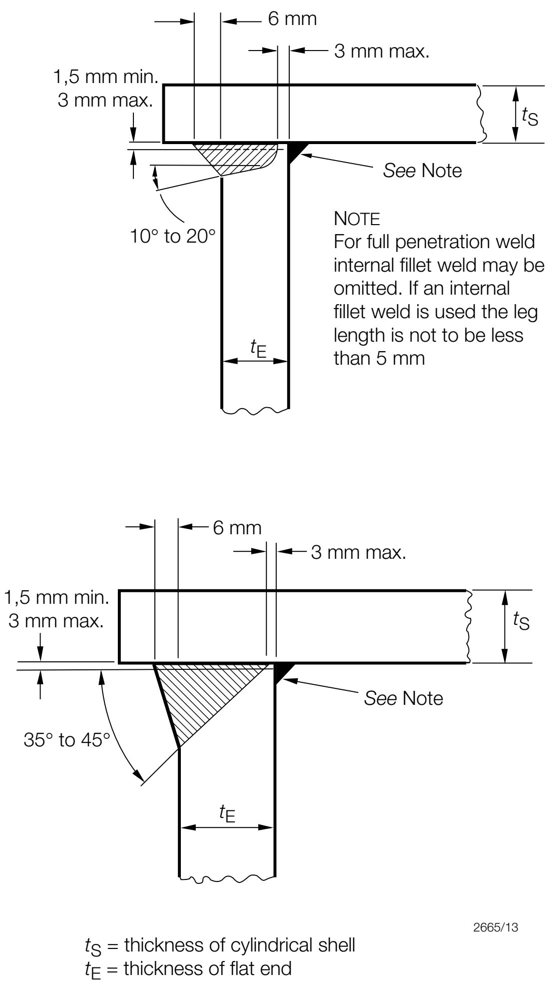


Fig. 1.9.1
Typical attachment of unflanged flat end plates to shell

9.1.4 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line distant 3,5 times the thickness of the plate from the outside of the plate, whichever is nearer to the flange.

9.1.5 Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

9.1.6 The thickness, t, of those portions of flat plates supported by stays and around tube nests is to be determined by the following formula:

$$t = Cd\sqrt{\frac{p}{\sigma}} + 0{,}75 \text{ mm}$$

where t, p and σ are as defined in 1.2

d = diameter of the largest circle which can be drawn through at least three points of support. At least one point of support must lie on one side of any diameter of the circle.

C = a constant, dependent on the method of support as detailed in 9.1.7. Where various forms of support are used, C is to be the mean of the values for the respective methods adopted.

9.1.7 The value of C in the formula in 9.1.6 is to be as follows:

(a) Where plain bar stays are strength welded into the plates as shown in Fig. 1.9.2
C = 0,134

(b) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in Fig. 1.9.3
C = 0,12 where the diameter of the washer is 3,5 times the diameter of the stay
C = 0,113 where the diameter of the washer is 0,67 times the pitch of the stays.

(c) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or, alternatively, is welded directly to shell, flue, furnace or wrapper, *see* 9.1.4 and 9.1.5):
C = 0,113

(d) Where the support is a gusset stay
C = 0,134

(e) Where the support is a tube secured as shown in Fig. 1.9.4
C = 0,144.

9.1.8 Where tubes are fixed by expanding only, sufficient tubes welded at both ends in accordance with Fig. 1.9.4 are to be provided within the tube nest to comply with 9.1.6, to carry the flat plate loading within the tube nest. Tubes welded in accordance with Fig. 1.9.4 are also to be provided in the boundary rows in sufficient numbers to carry the flat plate loading outside the tube areas.

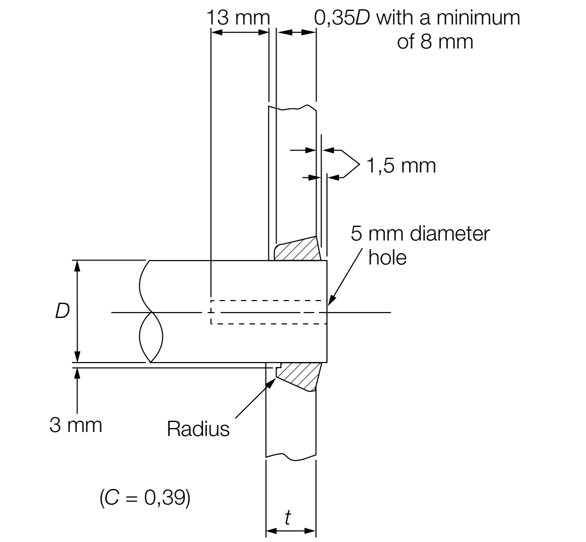
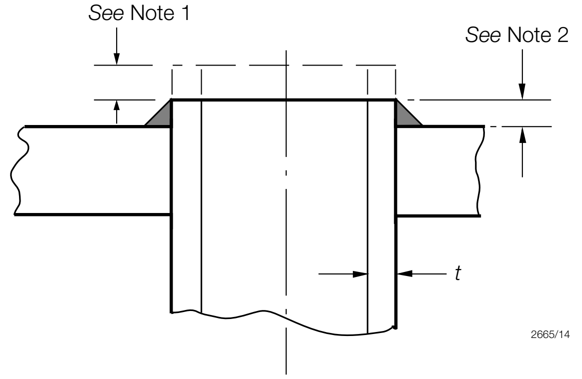
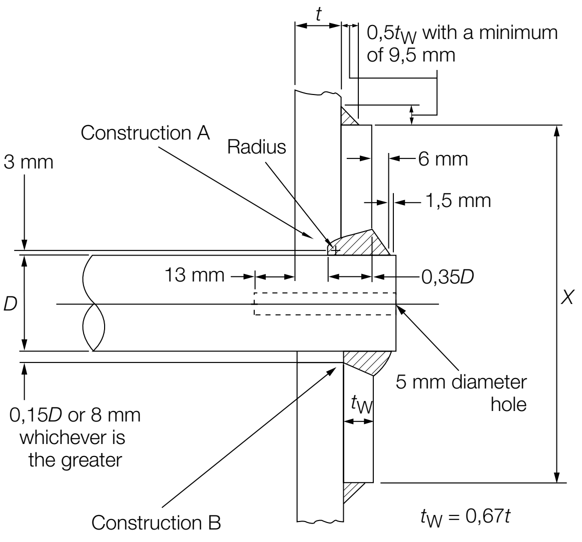


Fig. 1.9.2
Typical attachment of firebox, combustion chamber stays and bar stays



NOTES
1. The ends of the tubes are to be dressed flush with the welds when exposed to flame. When not exposed to flame the ends of the tubes may extend a maximum of 10 mm beyond the weld.
2. 3 mm minimum, but stress in weld due to nominal flat plate load carried by the tube not to exceed 70 N/mm^2. An equivalent recessed weld may be used.
3. Weld stress area is to be based on the weld throat area.

Fig. 1.9.4 Detail of weld for tube



Method of construction 'A' or 'B' may be used, except where t_W < 0,35*D*, construction 'A' is to be used.
where *X* = 3,5*D*, *C* = 0,12;
where *X* = 0,67 x pitch of stays, *C* = 0,113

Fig. 1.9.3 Typical attachment of bar stays

9.1.9 In the case of small boilers with a single tube nest of expanded tubes which does not exceed an area of 0,65 m^2, welded tubes need not be fitted provided the tubes are beaded at the inlet end. In this instance the support afforded by the expanded tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the nest and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin, as given by the formula in 9.4.1. The required tube plate thickness within such a tube nest is to be determined using the formula in 9.1.6, where:

C = 0,154
d = four times the mean pitch, in mm, of the expanded tubes in the nest.

9.1.10 The thickness, *t*, of any tube plate in the tube area is to be not less than that required for the surrounding plate determined by 9.1.6 and in no case less than:

(a) 12,5 mm where the diameter of the tube hole does not exceed 50 mm, or
(b) 14 mm where the diameter of the tube hole is greater than 50 mm.

9.1.11 Alternative methods of support will be specially considered.

9.1.12 The spacing of tube holes is to be such that the minimum width, *b*, in mm of any ligament between tube holes is not less than:

for expanded tubes:
b = 0,125*d* + 12,5 mm
for welded tubes:
b = 0,125*d* + 8 mm

where
d = diameter of the hole drilled in the plate, in mm.

9.1.13 Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is to be not less than:

$$H = \sqrt{tW}$$

where

t = thickness of plate, in mm
H = depth of flange, in mm
W = minor axis of manhole or sight hole, in mm.

9.1.14 Where the flat top plates of combustion chambers are supported by welded-on girders, the equation in 9.1.6 is to apply as follows:

(a) In the case of welded-on girders provided with waterways

C = 0,144

$$d = \sqrt{X^2 + Y^2}$$

where

X = width of waterway in the girder plus the thickness of the girder, in mm
Y = pitch of girders, in mm.

(b)In the case of continuously welded-on girders

C = 0,175
d = D

where

D = distance between inside faces of girders, in mm.

9.2 Combustion chamber tube plates under compression

9.2.1 The thickness of combustion chamber tube plates under compression due to the pressure on the top plate, based on a compressive stress not exceeding 96 N/mm^2 is to be determined by the following formula:

$$t = \frac{pWs}{1930\,(s - d)} \text{ mm}$$

where t and p are as defined in 1.2

d = internal diameter of the plain tubes, in mm
s = pitch of tubes, in mm, measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch
W = internal width of the combustion chamber, in mm, measured from tube plate to back chamber plate.

9.3 Girders for combustion chamber top plates

9.3.1 The formula in 9.3.2 is applicable to plate girders welded to the top combustion chamber plate by means of a full penetration weld.

9.3.2 The thickness of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:

$$t = \frac{0{,}32p\, l^2\, s}{d^2\, R_{20}} + 0{,}75 \text{ mm}$$

where t and p are as defined in 1.2

d = effective depth of girder, in mm
l = length of girder measured internally from tube plate to back chamber plate, in mm
s = pitch of the girders, in mm
R_{20} = specified minimum tensile strength of the girder plate, in N/mm^2.

9.4 Flat plate margins

9.4.1 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:

$$b = C\,(t - 0{,}75)\sqrt{\frac{\sigma}{p}} \text{ mm}$$

where p and σ are as defined in 1.2

t = thickness of the flat plate, in mm
b = width of margin, in mm
C = 3,12.

9.4.2 Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula in 9.4.1 is to be:

C = 2,38.

9.4.3 In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

9.4.4 Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from inside of the shell or the outside of the furnaces or flues, whichever is applicable.

9.4.5 In no case is the diameter D, in mm, of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:

$$D = \sqrt{\frac{345A}{p} + d^2}$$

where p is as defined in 1.2

d = external diameter of uptake, in mm
d_i = internal diameter of uptake, in mm
A = cross-sectional area of the uptake tube material, i.e. $\frac{\pi}{4}\,(d^2 - d_i^2)$ mm^2.

Section 10
Flat plates and ends of vertical boilers

10.1 Tube plates of vertical boilers

10.1.1 Where vertical boilers have a nest or nests of horizontal tubes, so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:

$$t = \frac{pD}{5J\,R_{20}} + 0{,}75 \text{ mm}$$

where t and p are as defined in 1.2

D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm

J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction)

$= \dfrac{s - d}{s}$

R_{20} = specified minimum tensile strength of tube plate, in N/mm^2

where

d = diameter of tube holes, in mm

s = vertical pitch of tubes, in mm.

10.1.2 Each alternate tube in the outer vertical rows of tubes is to be a tube welded at both ends as shown in Fig. 1.9.4. Further, the arrangement of tubes in the nests is to be such that the thickness of the tube plates meets the requirements of 9.1.

10.1.3 Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler the vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

10.2 Horizontal shelves of tube plates forming part of the shell

10.2.1 For vertical boilers of the type referred to in 10.1, in order to withstand vertical load due to pressure on the boiler ends, the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:

$$C = \frac{A\,D_i\,p}{t}$$

where

p = design pressure, in bar

t = thickness of the tube plate, in mm

A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm

D_i = inside diameter of the boiler, in mm.

10.2.2 For the combustion chamber tube plate the minimum number of gussets is to be:

1 gusset, where C exceeds 255 000
2 gussets, where C exceeds 350 000
3 gussets where C exceeds 420 000.

10.2.3 For the smokebox tube plate the minimum number of gussets is to be:

1 gusset where C exceeds 255 000
2 gussets where C exceeds 470 000.

10.2.4 The shell plates to which the sides of the tube plates are connected are to be not less than 1,6 mm thicker than is required by the formula applicable to shell plates with continuous circularity, and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (where R_{20} is the specified minimum tensile strength of the shell plates, in N/mm^2).

10.3 Dished and flanged ends for vertical boilers

10.3.1 The minimum thickness, t, of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$t = \frac{pR_i}{13\sigma} + 0{,}75 \text{ mm}$$

where t, p, R_i and σ are as defined in 1,2.

10.3.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

10.3.3 The inside knuckle radius, r_i, *see* Fig. 1.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

10.3.4 The inside radius of curvature of flange to uptake is to be not less than twice the thickness of the end plate, and in no case less than 25 mm.

10.3.5 If the dished end has a manhole, the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t\,W}$$

where

t = thickness of the flange, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

10.4 Flat crowns of vertical boilers

10.4.1 The minimum thickness of flat crown plates of vertical boilers is to be determined as in 9,1; *d* and *C* are defined as follows:

Where the crown is supported by an uptake only,

d = diameter, in mm, of the largest circle which can be drawn between the connections to the shell or firebox and uptake, *see* 9.1.1 to 9.1.5

C = 0,161

Where bar stays are fitted in accordance with 9.1.6 and 9.1.7,

d = diameter of the largest circle which can be drawn through at least three points of support, in mm

C = the mean of the values for the respective points of support through which the circle passes.

■ *Section 11*
Furnaces subject to external pressure

11.1 Maximum thickness

11.1.1 Furnaces, plain or corrugated, are not to exceed 22,5 mm in thickness.

11.2 Corrugated furnaces

11.2.1 The minimum thickness, *t*, of corrugated furnaces is to be determined by the following formula:

$$t = \frac{pD_o}{C}$$

where *p* is as defined in 1.2

t = thickness of the furnace plate measured at the bottom of the corrugations, in mm

C = 1060 for Fox, Morison and Deighton corrugations
= 1130 for Suspension Bulb corrugations

D_o = external diameter of the furnace measured at the bottom of the corrugations, in mm.

11.3 Plain furnaces, flue sections and combustion chamber bottoms

11.3.1 The minimum thickness, *t*, between points of substantial support, of plain furnaces or furnaces strengthened by stiffening rings, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \frac{pD_o (L + 610)}{102\,400} + 0{,}75 \text{ mm}$$

$$t = \frac{C\,p\,D_o}{1100} + \frac{L}{320} + 0{,}75 \text{ mm}$$

where *t* and *p* are as defined in 1.2

$C = \frac{2x}{x + \sigma}$ or 0,85 whichever is the greater

D_o = external diameter of the furnace, flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

x and σ are as defined in 11.7.1.

11.3.2 Where stiffeners are used for strengthening plain cylindrical furnaces, or combustion chambers, the second moment of area, I, of the stiffener is to be determined by the following formula:

$$I = \frac{p\,D_o^3\,L}{13{,}3 \times 10^6} \text{ mm}^4$$

where *p* is as defined in 1.2

D_o = external diameter of the furnace flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

For proportion of stiffening rings, *see* Fig. 1.11.1.

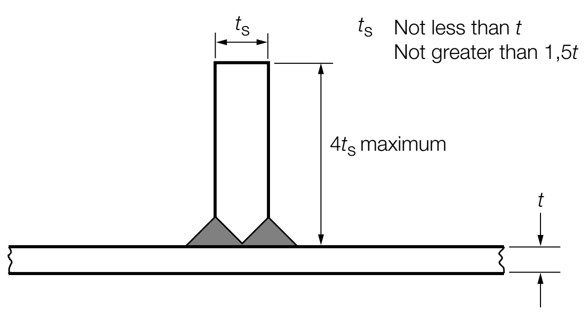


Fig. 1.11.1
Furnace, flue and combustion chamber stiffeners

11.4 Plain furnaces of vertical boilers

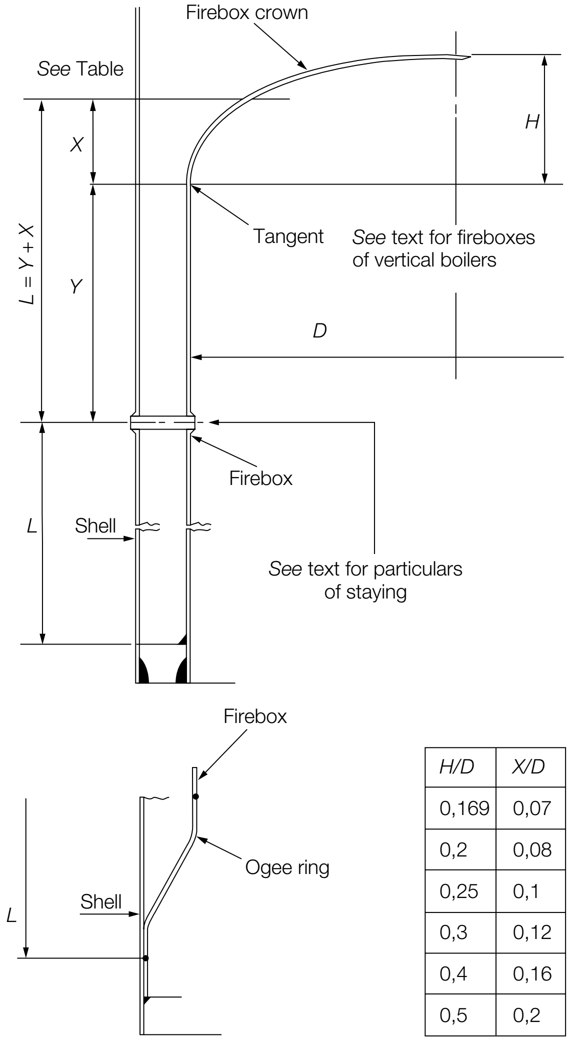
11.4.1 The thickness of plain furnaces not exceeding 2000 mm in external diameter is to be determined by the formulae given in 11.3.1, the greater of the two thicknesses being taken:

where

D_o = external diameter of the furnace, in mm. Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays

L = effective length, in mm, of the furnace between the points of substantial support as indicated in Fig. 1.11.2.

11.4.2 For furnaces under 760 mm in external diameter, the thickness is to be not less than 8 mm, and for furnaces 760 mm in external diameter and over, the thickness is to be not less than 9,5 mm.



H/D	*X/D*
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Fig. 1.11.2 Effective length, *L*, for use in 11.4

11.4.3 A circumferential row of stays connecting the furnace to the shell will be considered to provide substantial support to the furnace, provided that:

- The diameter of the stay is not less 22,5 mm or twice the thickness of the furnace, whichever is the greater.
- The pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

11.5 Hemispherical furnaces

11.5.1 The minimum thickness, *t*, of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:

$$t = \frac{C\,p\,R_o}{608} + 0{,}75 \text{ mm}$$

where *t* and *p* are as defined in 1.2
x and σ are as defined in 11.7.1

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outer radius of curvature of the furnace, in mm.

11.5.2 In no case is the maximum thickness to exceed 22,5 mm, or the ratio $\dfrac{R_o}{t - 0{,}75}$ to exceed 100.

11.6 Dished and flanged ends for supported vertical boiler furnaces

11.6.1 The minimum thickness, *t*, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are supported by central uptakes, is to be determined by the following formula:

$$t = \frac{p\,R_o}{10\sigma} + 0{,}75 \text{ mm}$$

where *t*, *p*, R_o and σ are as defined in 1.2.

11.6.2 The inside radius of dishing and flanging are to be as required by 10.3.

11.7 Dished and flanged ends for unsupported vertical boiler furnaces

11.7.1 The minimum thickness, *t*, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula, but is in no case to be less than the thickness of the firebox:

$$t = \frac{C\,p\,R_o}{660} + 0{,}75 \text{ mm}$$

where *t* and *p* are as defined in 1.2.

x = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for carbon and carbon manganese steel with a specified minimum tensile strength of 400 N/mm^2

$C = \dfrac{2x}{x + \sigma}$ or 0,85 whichever is the greater

R_o = outside radius of the crown plate, in mm $\left(\text{in no case is } \dfrac{R_o}{t} \text{ to exceed 88}\right)$

σ = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for the steel actually used.

11.7.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

11.7.3 The inside knuckle radius, r_i, *see* Fig.1.4.2(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate and in no case less than 65 mm.

11.8 Ogee rings

11.8.1 The minimum thickness, *t*, of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:

$$t = \sqrt{\frac{pD_i\,(D_i - D_o)}{9\,900}} + 0{,}75 \text{ mm}$$

where *t* and *p* are as defined in 1.2
D_i = inside diameter of boiler shell, in mm
D_o = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

11.8.2 Proposals to use a flat plate annular ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains any unbalanced vertical load on the furnace will be the subject of special consideration.

11.9 Uptakes of vertical boilers

11.9.1 The minimum thickness, *t*, of internal uptakes of vertical boilers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{pD_o\,(L + 610)}{102\,400}} + 4 \text{ mm}$$

$$t = \frac{p\,D_o}{1100} + \frac{L}{320} + 4 \text{ mm}$$

where *t* and *p* are as defined in 1.2
D_o = external diameter of uptake, in mm
L = length of uptake between the centres of points of substantial support, in mm.

Section 12
Boiler tubes subject to external pressure

12.1 Tubes

12.1.1 The thickness of tubes is to be in accordance with Table 1.12.1 for the appropriate outside diameter and design pressure.

12.1.2 Tubes may be welded at both ends, welded at the inlet end and expanded at the outlet end, or expanded at both ends. In addition to expanding, tubes may be bell mouthed or beaded at the inlet end. Where tubes are welded, the weld detail is to be as shown in Fig. 1.9.4 and the tubes are to be expanded into the tube plates in addition to welding, except as permitted by 12.1.3.

12.1.3 For tubes of thickness greater than 6,0 mm, expanding in addition to welding is not required if a recessed weld of depth not less than the tube thickness is provided.

Table 1.12.1 Thickness of plain tubes under external pressure

Design pressure, in bar											Thickness, in mm
Outside diameter, in mm											
38	44,5	51	57	63,5	70	76	82,5	89	95	102	
—	—	—	—	—	—	—	—	—	26,9	25,2	5,89
—	—	—	—	—	—	—	26,2	24,1	22,8	21,4	5,38
—	—	—	—	—	—	24,1	22,1	20,7	19,3	17,9	4,88
—	—	—	27,6	24,8	22,8	20,7	19,3	17,9	16,6	15,9	4,47
—	29,3	25,5	22,8	20,7	18,9	17,3	15,9	14,8	13,7	12,7	4,06
26,6	22,8	20,7	17,9	15,9	14,8	13,1	12,4	11,4	10,3	9,6	3,66
20,3	16,9	14,8	13,1	12,1	11,0	9,6	8,9	8,2	7,6	6,9	3,25
14,8	12,4	10,7	9,6	8,6	7,6	—	—	—	—	—	2,95

■ *Section 13* Tubes welded at both ends and bar stays for cylindrical boilers

13.1 Loads on tubes welded at both ends and bar stays

13.1.1 Each tube or bar stay is to be designed to carry its due proportion of the load on the plates which it supports.

13.1.2 For a tube or bar stay, the net area to be supported is to be the area, in mm^2, enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays enclosed. In the case of a tube or bar stay in the boundary rows, the support afforded by the flat plate margin, where applicable, should be taken into account. Where flat margins overlap stays are not required.

13.1.3 The thickness of tubes welded at both ends to tube plates is to be such that the longitudinal stress due to the flat plate loading does not exceed 70 N/mm^2.

13.1.4 Tubes may be welded into the boiler after post-weld heat treatment has been carried out.

13.1.5 The permissible longitudinal stress in combustion chamber bar stays or similar stays where an end is heated by flame, is not to exceed 70 N/mm^2, and the diameter of this type of bar stay is not to be less than 19 mm.

13.1.6 The permissible longitudinal stress in longitudinal bar stays not subject to heating, is not to exceed 20 per cent of the minimum specified tensile strength, in N/mm^2, and the diameter of this type of bar stay is not to be less than 25 mm.

■ *Section 14* Construction

14.1 Access arrangements

14.1.1 In watertube boilers, manholes are to be provided in all drums of sufficient size to allow access for internal examination and cleaning, and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers, and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

14.1.2 Cylindrical boilers are to be provided, where possible with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this there are to be sight holes and mudholes sufficiently large and numerous to allow the inside to be satisfactorily cleaned.

14.1.3 Where the cross tubes of vertical boilers are large, there is to be sight hole in the shell opposite to one end of each tube sufficiently large to allow the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

14.1.4 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

14.1.5 Doors for manholes, mudholes and sight holes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

14.1.6 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is to be not less than 16 mm.

14.1.7 Doors of the internal type for openings not larger than 230 mm x 180 mm need be fitted with one stud only, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is to be not less than the strength of the stud or bolt.

14.1.8 The crossbars or dogs for doors are to be of steel.

14.1.9 For smaller circular openings in headers and similar fittings, an approved type of plug may be used.

14.1.10 Circular flat cover plates may be fitted to raised circular manhole frames not exceeding 400 mm diameter, and for an approved design pressure not exceeding 18 bar.

14.1.11 External circular flat cover plates are to be in accordance with a recognised National Standard.

14.2 Torispherical and semi-ellipsoidal ends

14.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 1.14.1.

14.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

14.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 4.1.

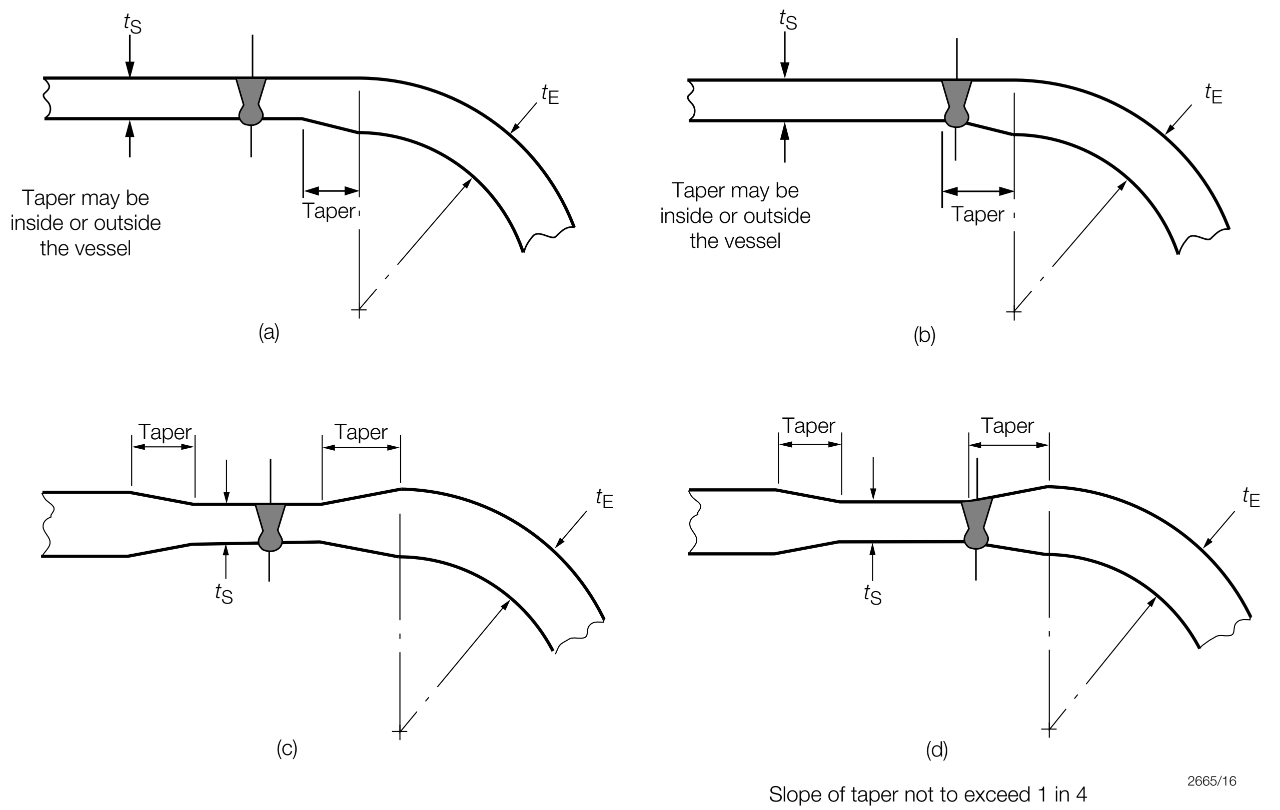


Fig. 1.14.1 Typical attachments of dished ends to cylindrical shells

14.3 Hemispherical ends

14.3.1 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be reduced by taper to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, *see* Fig. 1.14.2.

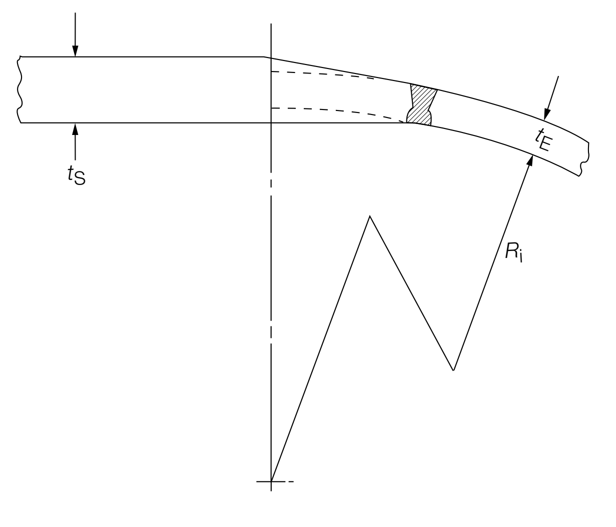


Fig. 1.14.2
Attachment of hemispherical end to cylindrical shell

14.3.2 If the hemispherical end is provided with a parallel portion, the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

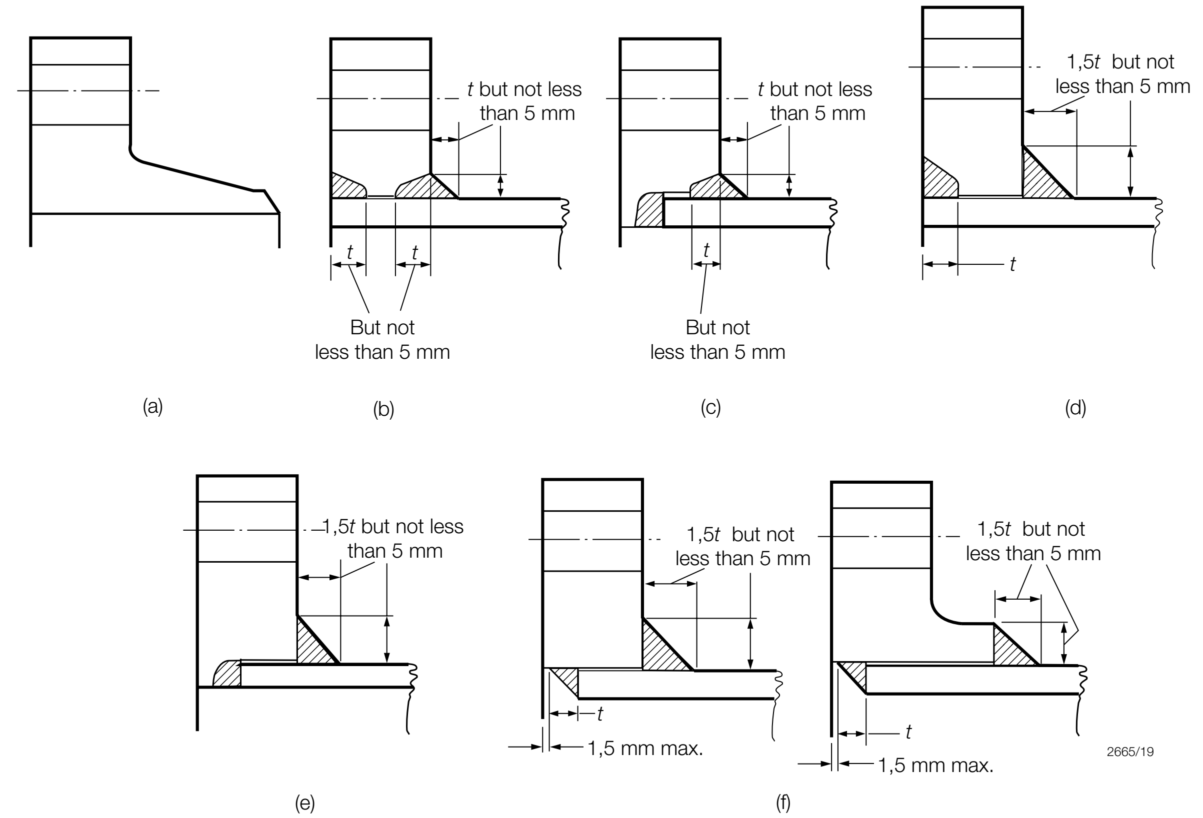
14.4 Welded-on flanges, butt welded joints and fabricated branch pieces

14.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

14.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

14.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

14.4.4 Typical examples of welded-on flange connections are shown in Fig. 1.14.3(a) to (f), and limiting design conditions for the flange types are shown in Table 1.14.1. In Fig. 1.14.3, t is the minimum Rule thickness of the standpipe or branch.



'*t*' is the minimum Rule thickness of standpipe or branch

Fig. 1.14.3 Typical examples of welded flange connections

Table 1.14.1 Limited design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)		No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

14.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

14.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

14.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of Pt 1, Ch 3.

14.4.8 Threaded sleeve joints complying with Pt 7, Ch 1,5.6.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

14.5 Welded attachments to pressure vessels

14.5.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as means of indicating any leakage during hydraulic testing and in service. *See* Pt 1, Ch 3.

14.5.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 1.14.4. Alternative methods of attachment may be accepted provided details are submitted for consideration.

14.5.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see* Fig. 1.14.4(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

14.6 Fitting of tubes in water tube boilers

14.6.1 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm in depth, measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is to be not less than 9,5 mm in depth.

14.6.2 Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm and where they are secured from drawing out by means of bellmouthing only, the included angle of belling is to be not less than 30°.

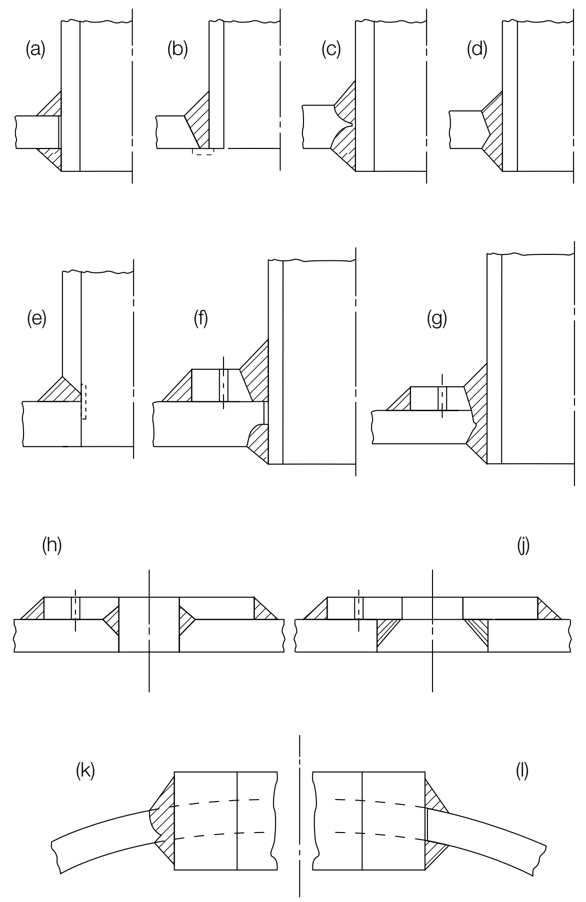


Fig. 1.14.4
Typical acceptable methods of attaching branches and pads

■ *Section 15*
Mountings and fittings for cylindrical and vertical boilers, steam generators, pressurised thermal liquid and pressurised hot water heaters

15.1 General

15.1.1 Valves over 38 mm diameter are to be fitted with outside screws, and the covers are to be secured by bolts or studs. All valves are to be arranged to shut with a right-hand (clockwise) motion of the wheels.

15.1.2 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter.

15.1.3 Where a superheater is fitted which can be shut-off from the boiler, it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

15.1.4 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 13,0 bar or to steam temperatures exceeding 220°C, and boiler blow-down fittings, are to be made of steel or other approved material.

15.2 Safety valves

15.2.1 Boilers and steam generators are to be fitted with not less than two safety valves, each having a minimum internal diameter of 25 mm, but those having a total heating surface of less than 50 m^2 may have one valve not less than 50 mm diameter. Small oil fired package boilers of the once through coil type used for auxiliary or domestic purposes, where the feed pump capacity limits the output, may have one safety valve not less than 19 mm internal diameter, or two safety valves with internal diameters not less than 16 mm, provided the capacity is in accordance with 15.2.11.

15.2.2 The valves, spindles, springs and compression screws are to be so encased and locked or sealed that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service.

15.2.3 Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats.

15.2.4 Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

15.2.5 Safety valves are to be made with working parts having adequate clearances to ensure complete freedom of movement.

15.2.6 Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

15.2.7 All the safety valves of each boiler and steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is to be of cross-sectional area not less than the aggregate area of the safety valves in the chest in the case of full lift valves, and one-half of that area in the case of other valves. For the meaning of aggregate area, *see* 15.2.11.

15.2.8 Each safety valve chest is to be drained by a pipe fitted to the lowest part and led with a continuous fall to the bilge or to a tank, clear of the boilers. No valves or cocks are to be fitted to these drain pipes. It is recommended that the bore of the drain pipes be not less than 19 mm.

15.2.9 Safety valves for shell type exhaust gas steaming economisers are to incorporate fail safe features which will ensure operation of the valve even with solid matter deposits on the valve and guide. Alternatively, a bursting disc discharging to a suitable waste steam pipe is to be fitted. These emergency devices are to function at a pressure not exceeding 1,5 times the economiser approved design pressure. Full particulars of the proposed arrangements are to be submitted for consideration.

15.2.10 Where the receiver is fitted with safety valves to relieve the steam output of the economiser and the economiser cannot be isolated from the receiver the requirements of 15.2.9 may be waived.

15.2.11 The designed discharge capacities of the safety valves on each boiler and steam generator are to be found from the following formulae:

Saturated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1}$$

Superheated steam safety valves:

$$E = \frac{AC\,(p + 1{,}03)}{98{,}1} \sqrt{\frac{V_S}{V_H}}$$

where

p = set pressure, in bar gauge

A = for ordinary, high lift or improved high lift safety valves, the aggregate area, in mm^2, of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions

= for full lift safety valves, the net aggregate area, in mm^2, through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted

C = 4,8 for valves of ordinary type having a minimum lift of $\frac{D}{24}$

= 7,2 for valves of high lift type, having a minimum lift of $\frac{D}{16}$

= 9,6 for valves of improved high lift type having a minimum lift of $\frac{D}{12}$

= 19,2 for valves of full lift type having a minimum lift of $\frac{D}{4}$

D = bore of valve seat, in mm

E = the maker's specified peak load evaporation, in kg/hour (including all evaporation from water walls, integral, or steaming economisers and other heating surfaces in direct communication with the boiler)

V_H = specific volume of superheated steam (m^3/kg)

V_S = specific volume of saturated steam (m^3/kg).

15.2.12 When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by LR, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a constant higher than C = 19,2, based on 90 per cent of the measured capacity up to a maximum of C = 45 for full lift safety valves.

15.2.13 Pressurised thermal liquid and pressurised hot water heaters are to be provided with a safety relief device.

15.3 Waste steam pipes

15.3.1 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it is to be at least 10 per cent greater than the aggregate area of the safety valves as used in the formulae in 15.2.11. For full lift and other approved valves of high discharge capacity, the cross-sectional area of the waste steam pipe and passages is to be not less than 0,1C times the aggregate valve area.

15.3.2 The cross-sectional area of the main waste steam pipe is to be not less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

15.3.3 Waste steam pipes are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

15.3.4 The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service, and in any case not less than 10 bar.

15.3.5 Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

15.3.6 The safety valves of each exhaust gas heated economiser and exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

15.3.7 External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

15.3.8 It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe.

15.4 Adjustment and accumulation tests

15.4.1 All safety valves are to be set under steam to a pressure not greater than the approved pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved design pressure. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to exceed 10 per cent of the design pressure. During this test no more feed water is to be supplied than is necessary to maintain a safe working water level.

15.5 Stop valves

15.5.1 One main stop valve is to be fitted to each boiler and secured directly to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary.

15.5.2 Where two or more boilers are connected together:

- Stop valves of self-closing or non-return type are to be fitted.
- Essential services are to be capable of being supplied from at least two boilers.

15.6 Water level indicators

15.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

15.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

15.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 15.7.1 provided that in the event of a power supply failure to that system an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

15.6.4 The water gauges are to be readily accessible and placed so that the water level is clearly visible. The lowest visible parts of water gauges, are to be situated at the lowest safe working level.

15.6.5 The level of the highest part of the effective heating surfaces, e.g. combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

15.6.6 The cocks of all water gauges are to be operable from positions free from danger in the event of the glass breaking.

15.7 Low water level fuel shut-off and alarm

15.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners, or any other fuel used to fire the boiler, when the water level falls to a predetermined low level. These level detectors, in addition, may be used for other functions, e.g. high level alarm, feed pump control, etc.

15.8 Feed check valves

15.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for essential services. The feed check and stop valves may be connected to a single standpipe at the shell. In the case of steam/steam generators one feed check valve is acceptable provided steam for essential services is simultaneously available from another source.

15.9 Pressure gauges

15.9.1 Each boiler is to be provided with a separate steam pressure gauge.

15.9.2 The gauges are to be placed where they are easily read.

15.10 Blow-down and scum valves

15.10.1 Each boiler is to be fitted with at least one blow-down valve.

15.10.2 The blow-down valve is to be attached, wherever practicable, direct to the lower part of the boiler. Where it is not practicable to attach the blow-down valve directly, a steel pipe supported from the boiler may be fitted between the boiler and valve.

15.10.3 The blow-down valve and its connections to the sea need not be more than 38 mm, and is to be not less than 19 mm internal diameter. For cylindrical boilers the size of the valve may be generally 0,0085 times the diameter of the boiler.

15.10.4 Blow-down valves and scum valves (where the latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

15.10.5 For blow-down valves or cocks on the ship's side and attachments, *see* Pt 7, Ch 2,2.

15.11 Salinometer valve or cock

15.11.1 Each boiler is to be provided with a salinometer valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

■ *Section 16*
Mountings and fittings for water tube boilers

16.1 General

16.1.1 Mountings and fittings not mentioned in this Section are to be in accordance with the requirements in Section 15.

16.2 Safety valves

16.2.1 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of 15.2.

16.2.2 Each saturated steam drum and each superheater are to be provided with at least one safety valve.

16.2.3 Where the superheater forms an integral part of the boiler, the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some Naval Authorities may limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity for the boiler, builders should give attention to any relevant requirements of the Naval Authority.

16.2.4 The boiler and superheater valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

16.2.5 Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

16.2.6 Where it is impracticable to attach safety valves directly to the superheater, the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

16.2.7 In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

16.3 Safety valve settings

16.3.1 All boiler and superheater safety valves are to be set under steam to their respective working pressures, which are not to be greater than the approved design pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved pressure.

16.3.2 In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

16.3.3 In no case is the superheater safety valve setting to exceed by more than three per cent the pressure for which the steam piping is approved.

16.4 Waste steam pipes

16.4.1 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 15.3.

16.4.2 In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service, adequate protection against heat effects is to be provided to the Surveyor's satisfaction.

16.4.3 Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere, with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

16.5 Accumulation tests

16.5.1 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

16.5.2 Where accumulation tests might endanger the superheaters, consideration will be given in cases of fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which LR is satisfied, by long experience of accumulation tests, that the capacity is adequate. When it is agreed to waive accumulation tests, it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

16.5.3 The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

16.6 Water level indicators

16.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

16.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

16.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by 16.7.1 provided that in the event of a power supply failure to that system an alarm is initiated and the oil fuel supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

16.6.4 Where a steam and water drum exceeding 4 m in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

16.6.5 The position of the glass water gauge of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold.

16.6.6 In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

16.7 Low water level fuel shut-off and alarm

16.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners when the water level falls to a predetermined low level. These level detectors may be used for other functions, e.g. high level alarm, feed pump control, etc.

16.7.2 Any proposals to depart from these requirements in the case of small auxiliary boilers will be the subject of special consideration.

16.8 Feed check valves and water level regulators

16.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

16.8.2 Where the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable, and the arrangements of check valves is to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

16.8.3 At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. *See* Pt 7, Ch 3,6 for arrangements and details of boiler feed systems.

16.8.4 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

16.8.5 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimising thermal stresses in these plates. Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

■ *Section 17* Hydraulic tests

17.1 General

17.1.1 Boilers and pressure vessels, together with their components are to withstand the following hydraulic tests without any sign of weakness or defect.

17.1.2 Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:

(a) boilers are to be tested on completion to a pressure 1,5 times the approved design pressure, or

(b) where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube holes, the test may be before drilling the tube holes, but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out. Where all the components have been tested as above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

17.2 Mountings

17.2.1 All boiler mountings are to be subjected to a hydraulic test of twice the approved design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is greater.

■ *Section 18* Control and monitoring

18.1 General

18.1.1 The Control and Monitoring systems are to comply with the requirements of Pt 9, Ch 1.

18.2 Automatic and remote controls

18.2.1 Where a boiler is fitted with automatic or remote controls so that under normal operating conditions it does not require normal intervention by the operators, it is to be provided with alarms and safety arrangements required by 18.2.2 to 18.2.5 and Table 1.18.1.

18.2.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery is required by Table 1.18.1, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

Table 1.18.1 Boilers: Alarms and safeguards

Item	Alarm	Note
Water level*	Low	Two water level sensors are to be provided each to operate independently, and automatically shut off the oil fuel to the burners and operate alarms. *See* Notes 1 to 3
Water level*	1st stage high 2nd stage high	Automatic closure of turbine steam inlet valves. *See* 18.2.2
Steam drum or superheater outlet pressure	High and low	—
Superheated steam temperature	High	—
De-superheated steam temperature*	High	—
Feed water forced circulation flow (if fitted)	Low	Oil fuel to burners to be shut off automatically
Feed water pH	Low	When automatic dosing of feed water fitted
Feed water salinity	High	Fitted in boiler feed system
Feed water temperature	Low	When automatic temperature control fitted
Combustion air pressure*	Low	Oil fuel to burners to be shut off automatically
Oil fuel pressure*	Low	—
Oil fuel temperature or viscosity*	High and low	Heavy oil only
Oil fuel atomising steam/air pressure	Low	—
Burner flame and ignition*	Failure	Each burner to be monitored. Oil fuel to burner(s) to be shut off automatically. *See* Note 4
Uptake temperature	High	Where economiser and/or gas air heaters are integral with the boiler and also for independent extended surface exhaust gas boilers/economisers, to monitor for soot fires

NOTES
1. For dual evaporation boilers the primary circuit is to be fitted with two independent low water level detectors which will operate alarms and shut off the oil fuel to the burners automatically. The secondary circuit is to be fitted with one low water level detector which will operate alarms and shut off the oil fuel to the burners automatically. Additionally one high water level alarm is to be fitted on the secondary circuit which may be operated by the same detector as that provided for low water level detection.
2. Only one independent system of low water level detection, alarm and automatic oil fuel shut off need be fitted in the case of small forced circulation or re-circulation coiled water tube ‘package’ type boilers when evaporation is less than 2900 kg/hr or the heating surface is less than 100 m^2.
3. Where two level sensors are provided these may be used for other functions, e.g. high level alarm, level control, trip systems. etc.
4. Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.
5. For boilers not supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, only the items marked* are required.

18.2.3 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:
(a) Combustion system.
(b) Oil fuel supply temperature or viscosity, heavy oil only.
(c) Boiler drum water level.
(d) De-aerator water level where applicable.
(e) Superheated steam pressure where applicable.
(f) Superheated steam temperature where applicable.
(g) De-superheated steam pressure where applicable.
(h) De-superheated steam temperature where applicable.

18.2.4 Burner controls are to be arranged such that light off is only possible at the minimum firing rate compatible with flame establishment.

18.2.5 Where water level indicators are dependent upon an external power supply, the oil fuel supply to the burners is to be automatically shut off in the event of power or signal failure.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in Chapter 1. The equations in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of Vol 1, Pt 2, Ch 5.

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of Chapter 1 are applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections 2 to 7 inclusive, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole, or opening, in mm
p = design pressure, *see* 1.3, in bar
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
s = pitch, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams, *see* 1.9, or ligament efficiency between tube holes (expressed as a fraction, *see* Ch 1,2.2)
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, *see* 1.8, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 Calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, *T*, used to evaluate the allowable stress, s, is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, *T*, for calculation purposes is to be not less than 50ºC.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar; or
(b) where the metal temperature exceeds 150°C; or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm, exceeds 157; or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Classes 2/1, 2/2 or 3 standards (as indicated above) will, if manufactured in accordance with the requirements of superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams, will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by 1.5.1, 1.5.2 and 1.5.3.

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc., it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Heat treatment, non-destructive and routine tests where required, for the four Classes of fusion welded pressure vessel are indicated in Table 2.1.1. Details of these requirements are given in Pt 1, Ch 3.

1.5.8 For a full definition of Classes of pressure vessels relating to boilers and associated pressure vessels, *see* Ch 1,1.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases, for fire-fighting or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres)
p is as defined in 1.2.1.

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Vol 1, Part 2. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of Lloyd's Register's (hereinafter referred to as 'LR') material certificate for such materials.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in Vol 1, Part 2, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term ‘allowable stress’, σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

Table 2.1.1 Heat treatment, non–destructive examinations and testing requirements

Class	Radiographic examination	Heat treatment	Routine weld tests	Hydraulic test
1	Required *see* Pt 1, Ch 3	*see* Pt 1, Ch 3	Required	Required
2/1	Spot required *see* Pt 1, Ch 3	*see* Pt 1, Ch 3	Required	Required
2/2	—	*see* Pt 1, Ch 3	Required	Required
3	—	—	—	Required

1.8.2 The allowable stress, s, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \qquad \sigma = \frac{R_{20}}{2,7} \qquad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, *T* for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, *T*, is to be used

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, *T*

T = metal temperature, *see* 1.4.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2 using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with Vol 1, Part 2, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Pt 1, Ch 3.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Classes 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Classes 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.

(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching flat ends *see* Fig. 1.8.2 and Fig. 1.9.1 in Chapter 1.

For typical acceptable methods of attaching dished ends *see* Fig. 2.8.1.

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in Sections 2 to 7, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures,

(b) weight of the vessel and normal contents under operating and test conditions,

(c) superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,

(d) reactions of supporting lugs, rings, saddles or other types of supports, or

(e) the effect of temperature gradients on maximum stress.

■ *Section 2*
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma J - 0,5p} + 0,75 \text{ mm}$$

where *t*, *p*, R_i and σ are as defined in 1.2

J = the joint factor of the longitudinal joints (expressed as a fraction). *See* 1.9 in the case of seamless shells clear of openings *J* = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1,5R_i$.

2.1.3 Irrespective of the thickness determined by the formula in 2.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

CROSS-REFERENCES

For efficiency of ligaments between tube holes, *see* Ch 1,2.2.
For compensating effect of tube stubs, *see* Ch 1,2.3.
For unreinforced openings, *see* Ch 1,2.4.
For reinforced openings, *see* Ch 1,2.5.

Section 3 **Spherical shells subject to internal pressure**

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J + 0{,}5p} + 0{,}75 \text{ mm}$$

where t, p, R_i, σ and J are as defined in 1.2.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.4 Openings in spherical shells requiring compensation are to comply in general, with Ch 1.2.5 using the calculated actual thickness of the spherical shell as applicable.

Section 4 **Dished ends subject to internal pressure**

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal, and hemispherical unstayed ends, and the knuckle section of torispherical ends dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where t, p, D_o, σ and J are as defined in 1.2.
K = a shape factor, *see* Ch 1,4.2 and Fig. 1.4.1.

4.1.2 For semi-ellipsoidal ends:
the external height, $H \geq 0{,}18D_o$
where
D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:
the internal radius, $R_i \leq D_o$
the internal knuckle radius, $r_i \geq 0{,}1D_o$
the internal knuckle radius, $r_i \geq 3t$
the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0{,}5D_o)\,(R_o + 0{,}5D_o - 2r_o)}\ .$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head made from more than one plate, in the crown section, is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where t, p, R_i, σ, and J are as defined in 1.2.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0{,}5\sqrt{R_i t}$ mm, before reducing to the crown thickness permitted by 4.1.4 where t = the required thickness from 4.1.1.

4.1.6 In all cases, H is to be measured from the commencement of curvature (shown in Fig. 1.4.2, in Chapter 1).

4.1.7 The minimum thickness of the head, t, is in no case to be less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in 1.2.

The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

4.1.8 For ends which are butt welded to the drum shell, *see* 1.9, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

CROSS-REFERENCES

For shape factors dished ends, *see* Ch 1,4.2.
For dished ends with unreinforced openings, *see* Ch 1,4.3.
For flanged openings in dished ends, *see* Ch 1,4.4.
For location of unreinforced and flanged openings in dished ends, *see* Ch 1,4.5.
For dished ends with reinforced openings, *see* Ch 1,4.6.

Section 5
Dished ends for Class 3 pressure vessels

5.1 Minimum thickness

5.1.1 As an alternative to the formula in 4.1.1, for Class 3 vessels only, the minimum thickness, t, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{p\,R_i}{C\,S}$$

where t, p, and R_i are as defined in 1.2

C = 2,57 for ends concave to pressure
 = 1,65 for ends convex to pressure
S = specified minimum tensile strength of plate, in N/mm^2, which should be not less than 410 N/mm^2.

5.1.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

5.1.3 The inside knuckle radius, r_i, of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

5.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

5.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by 5.1.1, is to be increased by 3 mm, and the total depth, H, of the manhole flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t_1\,W}$$

where
t_1 = required thickness of the plate, in mm
H = depth of flange, in mm
W = minor axis of the manhole, in mm.

Section 6
Conical ends subject to internal pressure

6.1 General

6.1.1 Conical ends and conical reducing sections, as shown in Fig. 1.5.1 in Chapter 1, are to be designed in accordance with the equations given in 6.2.

6.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in Fig. 1.5.1 in Chapter 1. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius when the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

6.1.3 Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

6.2 Minimum thickness

6.2.1 The minimum thickness, t, of the cylinder, knuckle and conical section at the junction and within the distance L from the junction is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where t, p, σ and J are as defined in 1.2
D_o = outside diameter, in mm of the conical section or end, *see* Fig. 1.5.1 in Chapter 1
K = a factor, taking into account the stress in the knuckle, *see* Table 1.5.1 in Chapter 1.

6.2.2 If the distance of a circumferential seam from the knuckle or junction is not less than L, then J is to be taken as 1,0; otherwise J is to be taken as the weld joint factor appropriate to the circumferential seam,
where
r_i = inside radius of transition knuckle, in mm, which is to be taken as $0{,}01D_c$ in the case of conical sections without knuckle transition
L = distance, in mm, from knuckle or junction within which meridional stresses determine the required thickness, *see* Fig. 1.5.1 in Chapter 1
 $= 0{,}5\sqrt{\dfrac{D_o\,t}{\cos\psi}}$
ψ = difference between angle of slope of two adjoining conical sections, *see* Fig. 1.5.1 in Chapter 1.

6.2.3 The minimum thickness, t, of those parts of conical sections not less than a distance L from the junction with a cylinder or other conical section, is to be determined by the following formula:

$$t = \frac{p\,D_c}{20\sigma\,J - p}\;\frac{1}{\cos\alpha} + 0{,}75 \text{ mm}$$

where
D_c = inside diameter, in mm, of conical section or end at the position under consideration, *see* Fig. 1.5.1 in Chapter 1
α,α_1,α_2 = angle of slope of conical section (at the point under consideration) to the vessel axis, *see* Fig. 1.5.1 in Chapter 1.

6.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

■ *Section 7* Standpipes and branches

7.1 Minimum thickness

7.1.1 The minimum wall thickness, *t*, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\,D_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}015D_o + 3{,}2 \text{ mm}$$

where t, p, D_o and σ are defined in 1.2.
If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\,t} \text{ mm.}$$

7.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by 2.1, 3.1 or 4.1 as applicable.

■ *Section 8* Construction

8.1 Access arrangements

8.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

8.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

8.1.3 Doors for manholes and sightholes are to be formed from steel plate or of other approved construction, and all jointing surfaces are to be machined.

8.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

8.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

8.1.6 The crossbars or dogs for doors are to be of steel.

8.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

8.2 Torispherical and semi-ellipsoidal ends

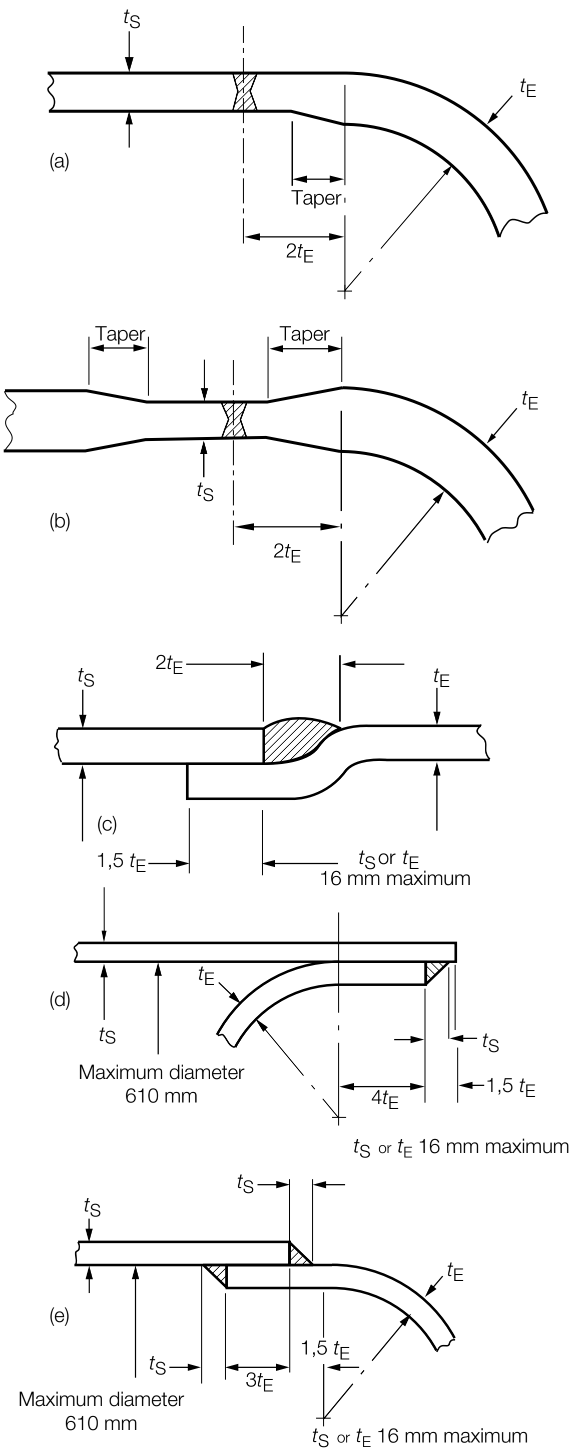
8.2.1 For typical acceptance types of attachment for dished ends to cylindrical shells, *see* Fig. 2.8.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

8.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

8.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

CROSS-REFERENCES

For hemispherical ends, *see* Ch 1,14.3.
For openings in flat ends, *see* Ch 1,8.3.
For unstayed circular flat end plates, *see* Ch 1,8.3.
For welded-on flanges, butt joints and fabricated branch pieces, *see* Ch 1,14.4.
For welded attachments to pressure vessels, *see* Ch 1,14.5.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Fig. 2.8.1
Typical attachment of dished ends to cylindrical shell

■ *Section 9*
Mountings and fittings

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

CROSS-REFERENCES

For starting air pipe systems and safety fittings, *see* Ch 2,7.

Section 10
Hydraulic tests

10.1 General

10.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_T} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

Section 11
Plate heat exchangers

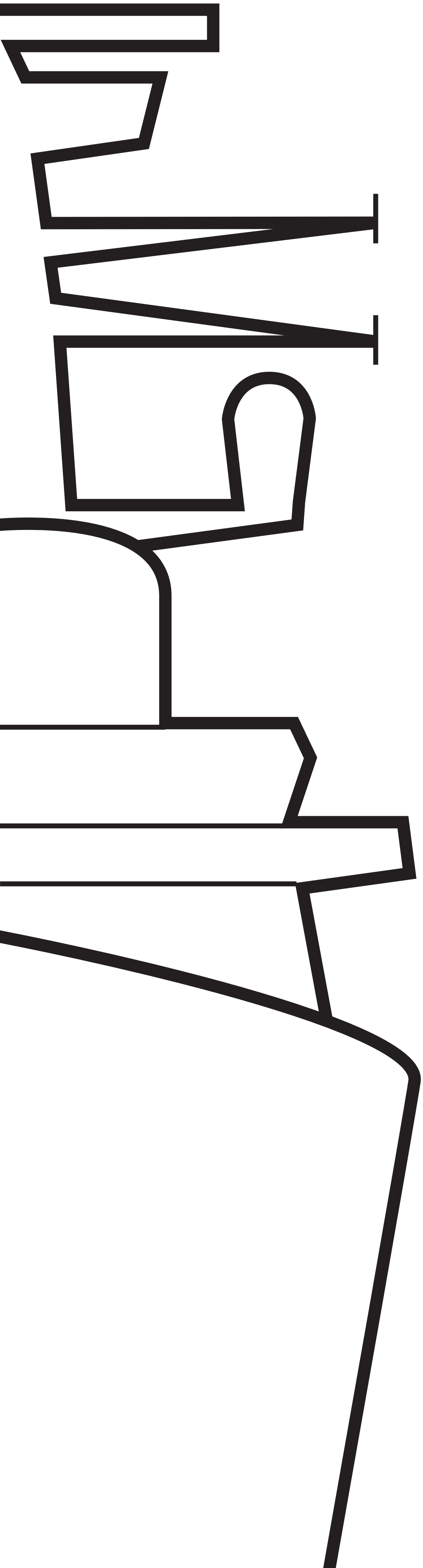
11.1 General

11.1.1 Plate heat exchangers are to be classed as follows. Class 2 where either of the following conditions apply:

(a) the maximum metal design temperature is 150°C or greater; or
(b) design pressure is 17,2 bar or greater.

Class 3 in all other cases.

11.1.2 Where the design temperature is equal to or lower than minus 10°C, a higher class is to apply.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 9*

Control engineering

January 2005

Lloyd's Register

Contents

■ *Section 1* General engineering systems

1.1 General requirements

1.1.1 This Chapter applies to systems providing control, alarm or safety functions for the following:

- Main propulsion systems.
- Steering and manoeuvring systems.
- Electrical power systems.
- Essential auxiliary machinery systems.
- Other engineering systems necessary for the watertight and weathertight integrity of the ship and functioning of ship type category systems.

1.1.2 Attention is to be given to any relevant requirements of the Naval Authority.

1.1.3 Section 2 states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.4 Section 3 states requirements which shall apply where it is intended to operate the ship with machinery spaces unattended. In general, naval ships complying with the requirements of Section 3 will be eligible for the class notation **UMS**.

1.1.5 Section 4 states requirements which shall apply where it is intended to operate the ship with machinery spaces under continuous supervision from a centralised control station. In general, naval ships complying with the requirements of Section 4 will be eligible for the class notation **CCS**.

1.1.6 Section 5 states requirements which shall apply where it is intended that the control and supervision of ship operational functions are computer based. In general naval ships complying with the requirements of of Section 5 will be eligible for the class notation **ICC**.

1.1.7 Electrical engineering arrangements and equipment are to comply with the requirements of Pt 10, Ch 1 as applicable.

1.2 Plans and information

1.2.1 Plans and information as detailed in 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 **General**. Description of operation (with explanatory diagrams), schematic diagrams of circuits, and lists of monitored parameters with relevant setpoints:

- Controllable pitch propellers.
- Electric generating plant.
- Incinerators.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified in other Sections of the Rules).
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waste-heat systems.
- Waterjets for propulsion purposes.

1.2.3 **Test schedules.** Test schedules for both works testing and sea trials, which should include methods of testing and test facilities, *see* 6.4.1.

1.2.4 **Alarm systems.** Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation.

1.2.5 **Programmable electronic systems.** (In addition to the documentation required by 1.2.2.)

- System requirements specification.
- Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
- Hardware certification details, *see* 2.9.4 and 2.11.3.
- Software quality plans, including applicable procedures, *see* 2.9.21.
- Factory acceptance, integration, harbour and sea trial test schedules for hardware and software.
- System integration plan, *see* 2.12.2.

1.2.6 **Control station.** Location and details of control stations, e.g. control panels and consoles.

1.2.7 **Fire detection systems.** Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.2.8 **Approved system.** Where it is intended to employ a standard system which has been previously approved, plans are not required to be submitted, providing there have been no changes in the applicable Rule requirements. Details of the previous approval are to be submitted.

1.2.9 **Cables.** For details of instrumentation and control requirements, *see* Pt 10, Ch 2,10.

1.2.10 **Lifts.** For details of alarms and safeguards for lifts classed by Lloyd's Register (hereinafter referred to as 'LR'), reference should be made to LR's *Code for Lifting Appliances in a Marine Environment*.

1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety functions for systems listed in 1.1.1 are to be surveyed at the manufacturers' works in accordance with the approved test schedule (*see* 1.2.3), and the inspection and testing are to be to the Surveyor's satisfaction, *see* 1.2.2.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the List of LR Type Approved Products published by LR.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable specialised naval standard, national or international standard, e.g. International Electrotechnical Commission, Publication 51 Recommendations for indicating electrical measuring instruments and their accessories.

1.3.5 Special consideration will be given to arrangements that comply with a relevant and acceptable specialised naval, national or international standard, such as IEC 60092-504, *Electrical Installation on Ships – Special Features: Control and Instrumentation*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 The essential features contained in 2.2 to 2.8 are to be incorporated in the design and installation of systems providing control, alarm or safety functions.

2.2 Control stations for machinery

2.2.1 Each machinery control station is to be provided with sufficient indication to ensure effective control of machinery and engineering systems and ready identification of faults. Indication should be provided, at least, for those parameters required to be monitored by relevant parts of these Rules.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.4 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.5 Control of machinery, and associated equipment is to be possible only from one station at a time.

2.2.6 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.7 For additional requirements where control stations incorporate visual display units and keyboard facilities, *see* 2.9.

2.3 Alarm systems, general requirements

2.3.1 Where an alarm system is to be provided, warning of faults in machinery and engineering systems, alarm information is to be displayed at the main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms (e.g. fire, general alarm).

2.3.4 Where alarms are displayed as group alarms provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.5 All alarms are to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

2.3.6 Acknowledgement of visual alarms is to be clearly indicated.

2.3.7 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible alarm or extinguish the visual alarm in that machinery space.

2.3.8 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible and visual alarms are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm at the main control room alarm display then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be re-initiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.9 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.10 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.11 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.12 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.13 The alarm system is to be capable of being tested during normal machinery operation, *see* 6.1.2.

2.3.14 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.15 Disconnection or manual overriding of any part of the alarm system should be clearly indicated.

2.3.16 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.17 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.18 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Where safety systems are provided the requirements of 2.4.2 to 2.4.12 are to be satisfied.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery; or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery; or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.5 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

2.4.6 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.7 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.8 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated.

2.4.9 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.10 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.11 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.4.12 As far as practicable, the safety system required by 2.4.2(b) is to be arranged to effect a rapid reduction in speed or power.

2.5 Control systems, general requirements

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.7 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.4 Control systems should be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.5 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control and indicate that the system is functioning correctly.

2.5.6 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.7 Arrangements are to be such that machinery may be operated with the system of remote or automatic controls out of action. This may be achieved by manual control or redundancy arrangements within the control system. Instrumentation and communications are to be provided at local manual control stations to ensure effective operation of the machinery.

2.6 Bridge control for main propulsion machinery

2.6.1 Where a bridge control system for main propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 The following indications are to be provided on the bridge:

(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for controllable pitch propeller. *See also* Pt 4, Ch 1,10.2.3.
(c) Direction and an indication representative of the magnitude of the thrust.
(d) Clutch position where applicable.
(e) Shaft brake position where applicable.

2.6.4 The propeller speed, direction of rotation and, if applicable, the propeller pitch are to be controlled from the bridge under all normal sea going and manoeuvring conditions.

2.6.5 Remote control of the propulsion machinery is to be from one control station at any one time, *see also* 2.2.5. Main propulsion control units on the navigating bridge may be interconnected. Means are to be provided at the main machinery control station to ensure smooth transfer of control between the bridge and machinery control stations.

2.6.6 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the propulsion machinery to be stopped in an emergency.

2.6.7 Audible and visual alarms are to operate on the bridge and in the alarm system required by 3.2 if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.8 At least two means of communication are to be provided between the bridge and the main control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply. *See also* 2.2.2 and Pt 1, Ch 2,5.9.

2.7 Valve control and indication systems

2.7.1 Systems providing remote control and indication functions for valves in Mobility and Ship Type category systems are to ensure effective operation, with due regard to any Naval Authority requirements for operation under damage conditions. The requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of control system power or actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Vol 1, Pt 3, Ch 4,7.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.13 are to be satisfied.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located on the navigating bridge unless specified otherwise by the Naval Authority.

2.8.4 An audible fire-alarm is to be provided having a characteristic tone distinguishing it from the alarm system required by 2.3 or any other alarm system. The audible fire-alarm is to be immediately audible throughout the machinery spaces, the navigating bridge and at manned watch positions as designated by the Naval Authority. Facilities are to be provided in the fire detection system to manually initiate the fire alarm from positions adjacent to all exits from machinery spaces, the navigating bridge and manned watch positions as designated by the Naval Authority.

2.8.5 The alarm system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire alarm. This alarm may be incorporated in the machinery alarm system as required by 2.3.

2.8.6 For electrical engineering requirements, *see* Pt 10, Ch 1,16.1.

2.8.7 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short circuit isolation units are to be Type Approved in accordance with Test Specification Number 1 given in LR's Type Approval System. For addressable systems, *see also* 2.9.

2.8.8 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.9 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.10 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.11 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.12 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire control panel for functional testing and reset of the system.

2.8.13 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

2.9 Programmable electronic systems – General requirements

2.9.1 The requirements of 2.9.2 to 2.9.21 are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. For essential services and safety critical systems, the requirements of 2.11 also apply.

2.9.2 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.9.3 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.9.4 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.11.3.

2.9.5 Where programmable electronic equipment shares resources, e.g. a data communication link, with any control, alarm or safety system for essential services or safety critical system, software is to meet the requirements of 2.11.7.

2.9.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.11.2 and/or 2.11.8.

2.9.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failure indications are to enable faults to be isolated at least down to the level of the lowest replaceable unit.

2.9.8 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply.

2.9.9 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

2.9.10 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.9.11 Displays and controls are to be protected against liquid ingress due to spillage or spraying.

2.9.12 User interfaces are to be designed in accordance with appropriate ergonomic principles to meet user needs and enable timely access to desired information or control of functions. A system overview is to be readily available.

2.9.13 The keyboard is to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

2.9.14 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

2.9.15 The size, colour and density of information displayed to the operator are to be such that information may be easily read from the normal operator position under all operational lighting conditions.

2.9.16 Display units are to comply with the requirements of International Electrotechnical Commission Standard IEC 950:1991, Safety of information technology equipment, including electrical business equipment, in respect of emission of ionising radiation.

2.9.17 Symbols used in mimic diagrams are to be visually representative and are to be consistent throughout the systems' displays.

2.9.18 Where data to be displayed on mimic diagrams is known to be unreliable, the mimic diagrams are to clearly identify the unreliable data.

2.9.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power supply (UPS).

2.9.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation from a multi-function display and control unit in the event of failure of any unit or any power supply.

2.9.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, Software engineering – Guidelines for the application of ISO 9001:2000 to computer software or an acceptable International, National or naval standard, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.10 Data communication links

2.10.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.10.2 to 2.10.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.10.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeater and power supplies.

2.10.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.11.2.

2.10.4 The properties of the data communication link, (e.g. bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.10.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.10.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 3.2 in the event of a failure of an active or standby component.

2.10.7 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.10.8 Data cables are to comply with the applicable requirements of Pt 10, Ch 1,10. Other media will be subject to special consideration.

2.10.9 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.10.10 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.11 Programmable electronic systems – Additional requirements for Mobility category and safety critical systems

2.11.1 The requirements of 2.11.2 to 2.11.10 are to be complied with where control, alarm or safety functions for Mobility category, or safety critical systems, incorporate programmable electronic equipment.

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards caused by engineering system failures, e.g. fire, explosion, etc., or to prevent mechanical damage which may result in the loss of a Mobility category system, e.g. main engine low lubricating oil pressure shutdown.
(b) Functions provided by Ship Type or Ancillary category systems may also be considered to be safety critical, e.g. domestic boiler low water level shutdown.

2.11.2 Alternative means of safe and effective control are to be provided for Mobility category systems. Back up control systems are to be of diverse design, and are to operate independently of the main control system. Where design diversity of control system software is not practicable, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.11.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to be certified in accordance with LR's Type Approval System.

2.11.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.11.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.11.6 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 3.2.

2.11.7 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard wired backup system, redundancy with design diversity, etc.

2.11.8 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.11.9 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.12 Programmable electronic systems – Additional requirements for integrated systems

2.12.1 The requirements of 2.12.2 to 2.12.5 apply to integrated systems such as those providing a grouping of fire safety or crew and embarked personnel emergency safety functions (*see* Pt 10, Ch 1), power management systems and integrated control, alarm and monitoring systems for machinery, and include the interconnection of systems capable of independent operation to provide co-ordinated functions or common user interfaces.

2.12.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements for all involved parties. This procedure is to be submitted for consideration where the integration involves control functions for Mobility category systems or safety critical functions.

2.12.3 The system requirements specification, *see* 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.12.4 In the event of failure of any part of the integrated system, only those functions that depend on the failed part are to be affected. Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures.

2.12.5 Where the integration involves control functions for essential services or safety functions, including fire safety or crew and embarked personnel or emergency safety functions, the Failure Mode and Effects Analysis (FMEA) required by Pt 1, Ch 2,3.3.8 is to additionally demonstrate that the integrated system will 'fail-safe', *see* 2.4.5 and 2.5.4, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.12.6 The quantity and quality of information presented to the Operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the Operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.12.7 Where information is required by the Rules or by Naval Authority requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also* 2.9.18.

■ *Section 3*
Unattended machinery space(s) – UMS notation

3.1 General

3.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in 3.2 to 3.7 are to be provided:

Air compressors.
Controllable pitch propellers and transverse thrust units.
Electric generating plant.
Incinerators.
Oil fuel transfer and storage systems (purifiers and oil heaters).
Propulsion machinery including essential auxiliaries.
Steam raising plant (boilers and their ancillary equipment).
Thermal fluid heaters.

3.1.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in the relevant Table of this Section, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required by the first stage alarm.

3.2 Alarm systems for machinery

3.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

3.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

3.2.3 The engineers' alarm required by 2.2.3 is to be activated automatically in the event that a machinery alarm has not been acknowledged in the space within a predetermined time.

3.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred;
(b) the machinery fault is being attended to; and
(c) the machinery fault has been rectified.

3.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shut down of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

3.3 Bridge control for propulsion machinery

3.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

3.4 Control stations for machinery

3.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

3.5 Fire detection alarm system

3.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

3.6 Bilge level detection

3.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

3.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a dewatering system should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

3.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

3.7 Supply of electric power, general

3.7.1 For naval ships operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on loss of the service generator. For naval ships operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services.

3.7.2 Alarms and safeguards are indicated in Table 1.3.1.

Table 1.3.1 Electric system: Alarms and safeguards

Item	Alarm	Note
Bus-bar voltage	High and low	—
Bus-bar frequency	Low	—
Operation of load shedding	Warning	—
Generator cooling air temperature	High	For closed air circuit water cooled machines

■ *Section 4* Machinery operated from a centralised control station – CCS notation

4.1 General requirements

4.1.1 Where it is proposed to install control, alarm and safety systems to the equipment listed in 3.1.1 the applicable features contained in 2.2 to 2.11 are to be incorporated in the system design.

4.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

4.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by 3.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided.

4.1.4 Additional requirements for controls, alarms and safeguards are given in 4.2.

4.2 Centralised control station for machinery

4.2.1 A centralised control station is to be provided at some suitable location,which satisfies the requirements of 4.2.2 to 4.2.7.

4.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

4.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

4.2.4 Indication of the operational status of running and standby machinery is to be provided.

4.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

4.2.6 In addition to the communication required by 4.2.5, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

4.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ *Section 5* Integrated computer control – ICC notation

5.1 General

5.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with 5.1 to 5.3 provides fault tolerant control and monitoring functions for one or more of the following services:
(a) Propulsion.
(b) Electrical generation and distribution (power management systems).
(c) Ballast.

5.1.2 A Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812 and the report and worksheets submitted for consideration, *see also* 2.12.5. The FMEA is to demonstrate that control and monitoring functions required by 5.2 will remain available at each operator station in the event of a single fault of the integrated computer control system, including input error, without adverse effect on the service(s).

5.1.3 Special consideration will be given to integrated computer control systems for other applications, except where these are addressed by other control engineering class notations. In particular, *see* Vol 3, Pt 1, Ch 4,5 for requirements of the optional class notation **IBS** – Integrated Bridge Navigation Systems.

5.2 General requirements

5.2.1 The integrated computer control system is to comply with the programmable electronic system requirements of 2.9 to 2.12 and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

5.2.2 Alarm displays are to be provided, in compliance with the requirements of 2.3, which ensure ready identification of faults in the equipment under control.

5.2.3 Alarm and indication functions required by 2.4 are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system. *See also* 2.11.8.

5.2.4 Controls are to be provided, in compliance with 2.5, to ensure the safe and effective operation of equipment and response to faults, e.g. stopping, starting, adjustment of parameters, etc. Indication of operational status and other such parameters, necessary to satisfy this requirement, is to be provided for all equipment under control by the integrated computer control system.

5.3 Operator stations

5.3.1 Each operator station allowing control of equipment is to be provided with a minimum of two multi-function display and control units. The number of units is to be sufficient to allow simultaneous access to control and monitoring functions required by 5.2.2 to 5.2.4. *See also* 2.9.18.

5.3.2 Each multi-function display and control unit is to include a monitor, keyboard and tracker ball. Alternative arrangements will be considered where these enable each unit to be configured by the user to provide required control or monitoring functions.

5.3.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g. in control, standby, etc.) is to be clearly indicated. *See also* 2.2.

5.3.4 Means of communication are to be provided between operator stations and any other stations from which the equipment may be controlled. The arrangements are to be permanently installed and are to remain operational in the event of failure of the main electrical power supply to the integrated control system.

■ *Section 6* **Trials**

6.1 General

6.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.3. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the ship. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

6.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

6.2 Unattended machinery space operation – UMS notation

6.2.1 In addition to the tests required by 6.1 the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

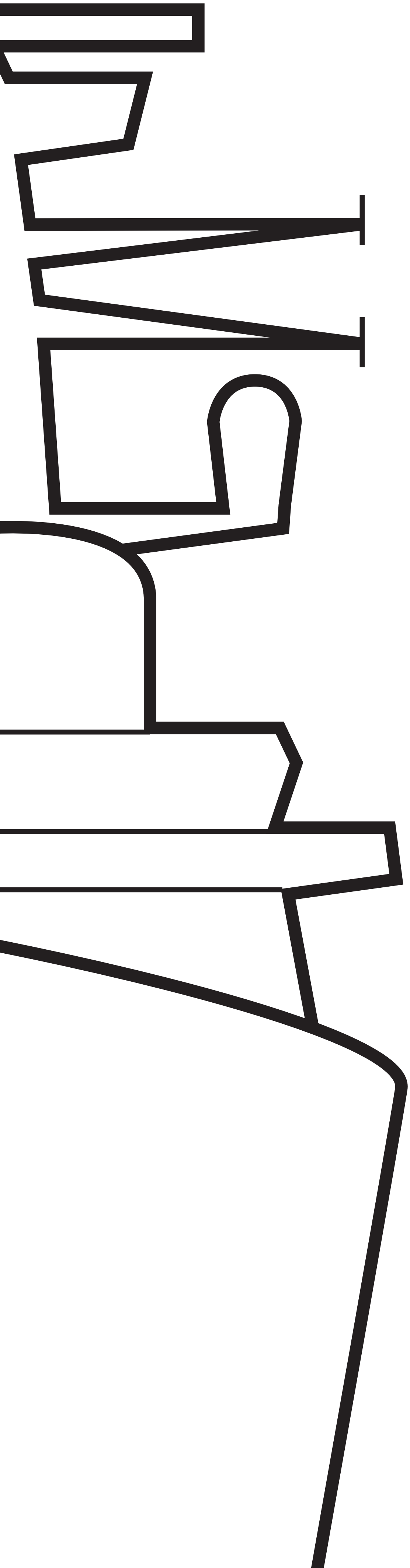
(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

6.3 Operation from a centralised control station – CCS notation

6.3.1 In addition to the tests required by 6.1, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

6.4 Record of trials

6.4.1 Two copies of the alarm and control equipment test schedules, as required by 1.2.3, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 10*

Electrical engineering

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Lloyd's Register

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■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to electrical engineering systems and equipment for naval ships.

1.1.2 Attention should also be given to any relevant requirements of the Naval Authority.

1.1.3 Electrical services required to maintain the ship in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power. The essential services for individual types of ships for seagoing, operational and habitable conditions on board are to be agreed by Lloyd's Register (hereinafter referred to as 'LR'). *See also* 1.5.1, 1.5.2 and 1.5.3.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of crew and ship from electrical hazards is to be ensured.

1.1.6 LR will be prepared to give consideration to cases where military arrangements require deviation from specific Rule requirements in this Chapter or where specialised naval standards, e.g. STANAG 1008 have been nominated and applied. Consideration will also be given to electrical arrangements of small ships and ships to be assigned class notation for restricted or special services.

1.1.7 Reference is to be made to Pt 1, Ch 2,4.8 concerning military requirements where these interface with the provisions of classification.

1.2 Plans

1.2.1 At least three copies of the plans and particulars in 1.2.2 to 1.2.12 are to be submitted for consideration. Single copies only are required of plans in 1.2.13 to 1.2.16. Additional copies are to be submitted when requested.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables; (normal operational and fault conditions);
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.2.3 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:
(a) protective devices, e.g. short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.2.4 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, details of circuit breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 10.6.2.

1.2.5 For naval ships in which explosive gas atmospheres may occur, the spaces are to be identified.

1.2.6 A schedule of electrical equipment located in hazardous areas giving details of:
(a) type of equipment;
(b) type of protection, e.g. Ex 'd';
(c) apparatus group, e.g. IIB;
(d) temperature class, e.g. T3;
(e) enclosure ingress protection, e.g. IP55;
(f) certifying authority;
(g) certificate number;
(h) location of equipment.

1.2.7 Simplified circuit diagram of electrical propulsion system (where fitted) giving details of:
(a) ratings of electrical machines, transformers, batteries and semiconductor converters;
(b) insulation type, size and current loadings of cables;
(c) make, type and rating of circuit breakers and fuses;
(d) instrumentation and protective devices;
(e) earth fault indication/protection;
(f) explanation of the system with details of the propulsion control systems and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of Section 15.

1.2.8 Details of electrically-operated fire, ship, crew and embarked personnel emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable to be employed for:
(a) emergency lighting (other than where accumulator emergency lanterns are to be installed);
(b) accommodation fire detection, alarm and extinction systems;
(c) crew and embarked personnel address system;
(d) general alarm;
(e) watertight doors, bow, stern and shell doors and other electrically operated closing appliances;
(f) low location lighting.

NOTE
A general arrangement plan of the complete ship showing the main vertical fire zones and the location of equipment and cable routes, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.9 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the crew and embarked personnel address system.

1.2.10 Documented test procedures to demonstrate compliance with STANAG 1008 where the electrical class notation **ELS** is required.

1.2.11 For battery installations, arrangement plans and calculations to show compliance with 11.5.

1.2.12 Plans of propulsion generators, motors, converting equipment, reactors and filters. In addition for all cables which pass through atriums or equivalent spaces and for vertical runs in trunks or other restricted spaces, information to show compliance with 10.8.8.

1.2.13 In order to establish compliance with 1.11.2 and 5.1.4 to 5.1.6, a general arrangement plan of the ship showing the location of major items of electrical equipment, for example:
- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.2.14 Arrangement plans of main and emergency switchboards, and section boards.

1.2.15 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected.

1.2.16 A Failure Modes Effects Analysis (FMEA) as required by Pt 1, Ch 2 is required to be submitted. The FMEA is to address a single failure of a system or item of equipment providing electrical power to those services listed in 1.5.1. It is not necessary to carry out the FMEA to component level, i.e. relays, printed circuit boards, etc., *see* Pt 1, Ch 2,17.1.5.

1.2.17 Where deviation from the specific requirements of these Rules is required, details of the arrangements with documented justification and/or analysis are to be submitted, *see* 1.1.6.

1.3 Surveys

1.3.1 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.3.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:
- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards.

1.3.3 For electric propulsion systems, in addition to the equipment listed in 1.3.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:
- cables;
- exciters;
- filters;
- reactors;
- slip ring assemblies

1.3.4 All other electrical equipment, not specifically referenced in 1.3.2 and 1.3.3, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of the Chapter.

1.4 Additions or alterations

1.4.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.4.3 All electric propelling machinery including switchgear, control gear, converters, cables, main and auxiliary generators, motors and exciters is to be surveyed by the Surveyors during manufacture and testing.

1.5 Definitions

1.5.1 Essential services are those necessary for the propulsion and safety of the ship within the Mobility category and Ship Type category (*see* Pt 1, Ch 1,3) and include the following:

- air compressors for oil engines;
- air pumps;
- automatic sprinkler systems;
- ballast pumps;
- bilge and dewatering system pumps;
- circulating and cooling water pumps;
- communication systems;
- condenser circulating pumps;
- electric propulsion equipment;
- electric starting systems for oil engines;
- extraction pumps;
- fans for forced draught to boilers;
- feed water pumps;
- fire detection and alarm systems;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the ship normally accessible to and used by personnel;
- made and clean water equipment;
- navigational aids where required by the Naval Authority;
- navigation lights and special purpose lights where required by the Naval Authority;
- oil fuel pumps and oil fuel burning units;
- oil separators;
- pumps for fire extinguishing systems;
- scavenge blowers;
- steering gear;
- thrusters for dynamic positioning;
- valves which are required to be remotely operated;
- ventilating fans for engine and boiler rooms;
- watertight doors, shell doors and other electrical operated;
- closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

Essential military systems and damage control arrangements relating to the Ship Type are to be stated where applicable.

1.5.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.5.3 Services such as the following, which are additional to those in 1.5.1 and 1.5.2, are considered necessary to maintain the ship in a normal seagoing operational and habitable condition:

- hotel services, other than those required for habitable conditions;
- thrusters, other than those for dynamic positioning.

1.5.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also* 5.1.3.

1.5.5 A 'switchboard' is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.5.6 A 'section board' is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.5.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.5.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.5.9 'Special category spaces' are those enclosed spaces above or below the weather deck intended for the carriage of motor vehicles, helicopters and aircraft with fuel in their tanks, into and from which such equipment can be moved, and to which crew have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles, helicopters and aircraft does not exceed 10 m.

1.5.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

1.5.11 'Dead ship condition' means that entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be made available to start the emergency generator at all times.

1.6 Design and construction

1.6.1 Electrical propelling machinery and associated equipment together with equipment for services essential for the propulsion and safety of the ship are to be constructed in accordance with the relevant requirements of this Chapter.

1.6.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.6.3 Electrical equipment shall be of a type tested and found suitable for use in a marine environment.

1.7 Quality of power supplies

1.7.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.7.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals.

(a) voltage:
permanent variations +6%, –10%
transient variations due to step changes in load +20%, –15%
recovery time 1,5 seconds

(b) frequency:
permanent variations ±5%
transient variations due to step changes in load ±10%
recovery time 5 seconds
A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.7.3 **Harmonics.** Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and maybe calculated using the expression:

$$V_T = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1}$$

where
V_T = total harmonic voltage
V_h = rms amplitude of a harmonic voltage of order h
V_1 = rms amplitude of the fundamental voltage.

1.7.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

Voltage tolerance (continuous)	±10%
Voltage cyclic variation deviation	5%
Voltage ripple	10%
(a.c. rms over steady state d.c. voltage)	

1.7.5 Where the electrical class notation **ELS** is to be assigned, the quality of electrical supplies is to comply with STANAG 1008. Reference is to be made to 1.8.

1.7.6 Where weapons or other combat systems may degrade the quality of power supplies, relevant details are to be advised to LR and to the prime contractor in order that the consequences may be established.

1.8 Quality of power supplies – ELS notation

1.8.1 Where the quality and arrangements of the generation and distribution power supplies meet an accepted and relevant national or international defined standard, such as STANAG 1008, suitable to supply sensitive military loads in both weapons and control systems (including pulsed and other special requirements) the class notation **ELS** may be assigned. The electrical system is to be stable under foreseen operational conditions when supplying these and other normal seagoing loads.

1.8.2 The quality of the main generation and distribution power supplies to the sensitive military loads are to comply with the defined standard, in place of the limits specified by 1.7.2 and 1.7.3.

1.8.3 The main generation and the distribution power supplies to the sensitive military loads are to be of an insulated type in compliance with 5.4. *See also* 5.5.7.

1.8.4 A systematic procedure incorporating verification and validation methods is to be used to ensure successful implementation of the defined standard. A quality plan is to be submitted that describes this procedure along with the results of the design validation providing:

- details of any power system analysis software and the input data used;
- a transient stability analysis, unless the generator and load characteristics indicated by 8.4 are shown to be representative of the system under consideration;
- a harmonic distortion analysis, if the sum of loads that distort the current waveform is greater than 1 per cent of the short circuit power of the generating capacity.

1.8.5 Where a transient stability analysis demonstrates that the defined standard requirements can be satisfied by generator control requirements different to those specified by 8.4, these may be accepted as equivalent to the Rules.

1.8.6 Unless it can be satisfactorily shown by the design verification and validation process that the requirements of the defined standard can be met, then measurements are to be taken as specified in 20.2.5.

1.9 Ambient reference conditions

1.9.1 The rating for classification purposes of essential electrical equipment intended for installation in ships to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a sea-water temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed. The requirement excludes military aspects that are required to be defined by Pt 1, Ch 2,4.8.

1.9.2 In the case of a ship to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service. *See* Vol 1, Pt 1, Ch 2.

1.10 Inclination of ship

1.10.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 2.4.1 in Pt 1, Ch 2,4.5.

1.11 Location and construction

1.11.1 All electrical equipment is be constructed or selected and installed such that:
(a) live parts cannot be inadvertently touched, unless they are supplies at the safety voltage specified in 1.12.2(h);
(b) it does not cause injury when handled or touched in the normal manner; and
(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Where not exposed to direct liquid spray, electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements. Where the equipment may be exposed to direct liquid spray the degree of protection is not to be less than IPX4. Where the equipment may be exposed to possible liquid immersion, the degree of protection is not to be less than IPX7.

1.11.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.11.3 Electrical equipment, as far as is practicable, is to be located:
(a) such that it is accessible for the purpose of maintenance and survey;
(b) clear of flammable material;
(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.8;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 13;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:
(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE
Compliance with IEC Publication 60695; Fire hazard testing, or an alternative and acceptable standard, will satisfy this requirement, *see also* 1.14.4.

1.11.5 Insulating materials and insulated windings are to be oil resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.11.6 Studs, screw-type of spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also* 10.14. There is to be adequate space and access for the terminations.

1.11.7 Equipment is not to remain live through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs. Where equipment such as anti-condensation heaters is fed from a supply separate from the main supply, isolation arrangements are to be provided.

1.11.8 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice. This requirement excludes military aspects that are required to be defined by Pt 1, Ch 2,4.8.

1.11.9 All nuts and screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.11.10 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.11.11 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level under the normal angles of inclination given in 1.9 for essential electrical equipment, *see* Pt 7, Ch 2,4. This requirement excludes military aspects that are required to be defined by Pt 1, Ch 2,4.8.

1.12 Earthing of non-current carrying parts

1.12.1 Except where exempted by 1.12.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed for personal protection against electric shock.

1.12.2 The following parts may be exempted from the requirements of 1.12.1:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 55 V direct current or 55 V, root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.12.3 Armouring, braiding and other metal coverings are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 13.8.3 for earthing of cables in dangerous zones or spaces.

1.12.4 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.12.5 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration. It is recommended that earthing conductors carrying RF currents should be solid strip, not braid, to minimise the impedance.

1.12.6 The nominal cross-section areas of copper earthing conductors for electrical equipment are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2, with a minimum of 1,5 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2.

1.12.7 The nominal cross-section areas of copper earthing conductors for armouring, braiding and other metal coverings of cables are, in general, to be equal to the equivalent cross-section of the armouring, braiding and other metal coverings with a minimum of 1,5 mm^2.

1.12.8 Earthing conductors of materials other than copper are to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.12.9 The connection of the earthing conductor to the hull of the ship is to be made in an accessible position, and is to be secured by a screw or stud of diameter not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.13 Bonding for the control of static electricity

1.13.1 Bonding straps for the control of static electricity are required for refuelling tanks and piping systems, for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.13.2 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of about 10 mm^2, and are to comply with 1.11.6 and 1.11.8.

1.14 Alarms

1.14.1 Where alarms are required by this Chapter they are to be arranged in accordance with Pt 9, Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual alarms, except in areas having high levels of background noise, such as machinery spaces.

1.14.2 The alarms in this Chapter are additional to those required by Pt 9, Ch 1; they may however form part of the alarm system that is required by Pt 9, Ch 1.

1.14.3 Cables for emergency alarms and their power sources are to be in accordance with 1.14.

1.14.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.14.

1.15 Operation under fire conditions

1.15.1 As a minimum, the following emergency services and their emergency power supplies are required to be capable of being operated under fire conditions:

- Control and power systems to power-operated fire doors and status indication for all fire doors.
- Control and power systems to power-operated watertight doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Fire safety stops, *see also* 16.5.
- Low location lighting, *see also* 17.4.3.
- Crew and embarked personnel address systems.

1.15.2 Where cables for the emergency services listed in 1.15.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the emergency service in any other area or zone. This may be achieved either by:

- cables being of a fire resistant type complying with 10.5.3, and at least extending from the main control/ monitoring panel to the nearest local distribution panel serving the relevant area or zone; or
- there being at least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

1.15.3 Where the cables for the power supplies for the emergency services listed in 1.15.1 pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be of a fire resistant type complying with 10.5.3, extending at least to the local distribution panel serving the relevant area or zone.

1.15.4 Fire resistant electrical cables for the emergency services listed in 1.15.1, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.16 Protection of electrical equipment against the effects of lightning strikes

1.16.1 In addition to the primary protection requirements in Section 19, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

1.17 Electrical supplies to systems fulfilling military requirement

1.17.1 With the exception of dedicated electrical supplies to systems fulfilling military requirements, all other electrical supplies are to comply with these Rules. The Rules are applicable to electrical equipment and systems to the point of isolation of the military system or equipment. The point of isolation is the supply side of the isolating switch, MCCB panel, fuse panel or distribution panel dedicated to the military system or equipment.

1.17.2 Dedicated electrical supply arrangements to military systems are to be in accordance with recognised international/national/specialised naval standards.

1.17.3 Where isolating equipment is used for both military and other services, the Rule requirements are to be applied.

1.17.4 Automatic, hand and emergency changeover switches to military systems on the ship's supply system are to comply with these Rules.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions. *See* 15.2.5 for electric propulsion systems;

(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3.

2.2.2 The arrangement of the ship's main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Arrangements are to be provided to prevent overloading of the generating set(s) supplying the electrical power that is/are required to maintain the ship in a normal operational and habitable condition. On loss of electrical power, arrangements are to be made for a standby generator set to be started, connected to the switchboard and essential services restarted in as short a time as is practicable. These load control, starting and restart functions may be achieved by the actions of suitably trained personnel but in ships with **UMS** notation the arrangements are to be automatic, *see also* 6.9.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets prime movers are to comply with the requirements of Pt 2, Ch 1,7 as applicable.

2.3.2 When the emergency source of electrical power is required to be used to restore propulsion from a dead ship condition, the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the dead ship condition. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in Section 3. *See* Pt 2, Ch 1,7 for initial starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets prime movers is to meet the requirements of Pt 2, Ch 1,9.3.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.7.2.

■ *Section 3*
Emergency and alternative sources of electrical power

3.1 General

3.1.1 The requirements of this Section apply to naval ships to be classed for unrestricted service. Alternative arrangements in accordance with the requirements of the Naval Authority may also be acceptable.

3.1.2 A greater or lesser period than the 18 hour period specified in 3.2.5 may be considered in conjunction with the operational requirements of the Naval Authority and any assigned Service Restriction.

3.1.3 Where the main sources of electrical power are located in two or more compartments that are not contiguous with each other, and where each source has its own independent self-contained systems, including power distribution and control systems, such that a fire or casualty in any one of the compartments will not affect the power distribution from the other(s), or to the services required by 3.2.5, the requirement of this section will be satisfied without an additional emergency source of electrical power and its associated transitional source of power, provided that:

(a) there is at least one generating set complying with the requirements of 2.2 and of sufficient capacity to meet the requirements of 3.2.5 in at least two non-contiguous compartments; and

(b) the generator sets referred to in 3.1.3(a) and their self-contained systems are installed such that one of them remains operable after damage or flooding in any one compartment; and

(c) the requirements of this Chapter applicable to the emergency source or any associated equipment are to be applied to the main source complying with 2.2, or any associated equipment.

3.2 Emergency source of electrical power

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

3.2.3 The location of the emergency source of electrical power and associated transforming equipment, if any, the transitional source of emergency power, the emergency switch- board and the emergency lighting switchboard in relation to the main source of electrical power, associated transforming equipment, if any, and the main switchboard are to be such as to ensure that a fire or other casualty in the space containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard, or in any machinery space of Category A will

not interfere with the supply, control and distribution of emergency electrical power. The space containing the emergency source of electrical power, associated transforming equipment, if any, the transitional source of emergency electrical power and the emergency switchboard is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing the main source of electrical power, associated transforming equipment, if any, and the main switchboard. Where this is not practicable, details of the proposed arrangements are to be submitted.

3.2.4 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

3.2.5 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) For a period of not less than three hours, emergency lighting at every lifeboat preparation station, muster and embarkation station and over the sides.

(b) For a period of not less than 18 hours, emergency lighting as detailed below unless alternative arrangements are provided by lamps having accumulator batteries within the lighting unit that are continuously charged:
- (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
- (ii) in the machinery spaces and main generating stations including their control positions;
- (iii) in all control stations, machinery control rooms, and at each main and emergency switchboard;
- (iv) at all stowage positions for firemen's outfits;
- (v) at the steering gear; and
- (vi) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors.

(c) For a period of not less than 18 hours:
- (i) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force; and
- (ii) The radiocommunications, as required by Amendments to SOLAS 1974, Chapter IV (*see also* 3.5 Radio installation).

(d) For a period of not less than 18 hours:
- (i) all internal communication equipment as required in an emergency;
- (ii) the navigational aids as required by the Naval Authority;
- (iii) the fire detection and fire-alarm system; and
- (iv) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency;

unless such services have an independent supply for the period of not less than 18 hours from an accumulator battery suitably located for use in an emergency.

(e) For a period of 18 hours the emergency fire pump if dependent upon the emergency generator for its source of power.

(f) The steering gear for the period of time required by Pt 6, Ch 1,9.

(g) Where applicable, the services required by 2.3.2.

(h) Engine cooling water and lubricating oil pumps, if independently driven.

3.2.6 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
- (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43ºC;
- (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.2.7 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are to be connected automatically to the emergency generator; and
- (iii) provided with a transitional source of emergency electrical power as specified in 3.2.7 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
- (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
- (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power;
- (iii) immediately supplying at least those services specified in 3.2.7; and
- (iv) remote control of fire extinguishing systems if electrical.

3.2.7 The transitional source of emergency electrical power where required by 3.2.6 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.2.5(a), (b) and (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
(b) all services required by 3.2.5(d)(i), (iii) and (iv) unless such
services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

3.2.8 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.9 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.10 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged.

3.2.11 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.12 In order to ensure ready availability of the emergency source of electrical power, and to ensure its continued safe operation, arrangements are to be made where necessary to disconnect automatically non-emergency circuits from the emergency switchboard to ensure that electrical power will be available automatically to the emergency circuits.

3.2.13 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.3 Starting arrangements

3.3.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Pt 2, Ch 1,7.6.

3.4 Prime mover governor

3.4.1 Where the emergency source of power is a generator, the governor is to comply with 2.5.

3.5 Radio installation

3.5.1 Every radio installation as required by the Naval Authority is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.5.2 A reserve source or sources of energy is to be provided on every ship, for the purpose of conducting distress and safety radiocommunications, in the event of failure of the ship's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the ship is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT ship earth station and any of the additional loads mentioned in 3.5.4, 3.5.5 and 3.5.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.5.3 The reserve source or sources of energy is to be independent of the propelling power of the ship and the ship's electrical system.

3.5.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.5.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.5.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or
(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.5.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.5.1.

3.5.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.5.7 If an uninterrupted input of information from the ship's navigational or other equipment to a radio installation as referred to in 3.5.1 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the ship's main or emergency source of electrical power.

■ *Section 4* External source of electrical power

4.1 Temporary external supply

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing fuses and terminals including one earthed, of ample size and suitable shape to facilitate an appropriate supply.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase:
  (i) three-wire
  (ii) four-wire with neutral solidly earthed but without hull return.

NOTE:
Where the **ELS** notation is to be assigned, earthed systems are permitted only when the additional requirements of 5.5.7 are satisfied. *See also* 1.8.3.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

15 000 V for generation and power distribution;
500 V for cooking and heating equipment permanently connected to fixed wiring;
250 V for lighting, heaters in cabins and crew and embarked personnel rooms, and other applications not mentioned above.

Voltages above these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in a space containing any of the main sources of electrical power will not render inoperable any of the other main sources of electrical power, or any emergency supply system if fitted.

5.1.4 Main switchboards, lighting distribution boards and any converting equipment are to be so placed relative to their associated generator(s) so that, as far as is practicable, the integrity of the main system(s) of supply will be affected only by a fire or other casualty in one space. Switchboards are to be located as close as practicable to their associated generators.

5.1.5 The arrangement of the emergency system of supply, where fitted, is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the ship.

5.1.6 Distribution systems are to be so arranged that a fire in any one main fire zone will not interfere with either the main or emergency distribution systems and services in any other such zone.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by a multi-pole linked circuit breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.2.2 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section-board.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:
(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.
In addition the requirements of 5.3.2 and 5.3.3 are to be complied with.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:
(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit. In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches.
For circuit breakers, *see* 6.5.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:
(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit. In addition, the requirements of 5.3.5 and 5.3.6 are to be complied with.

5.3.5 The switching device required by 5.3.4 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.6 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.4 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.3.7 Where high voltage equipment is contained in a room, or protected area, which also forms its enclosure, the access door(s) is to be so interlocked that it cannot be opened until the high voltage supply(ies) to the equipment is switched off. Provision is also to be made to enable the equipment and its cable(s) to be earthed down and any stored energy dissipated, sufficient to ensure personnel safety.

5.3.8 The access to the space(s) described in 5.3.7 are to be suitably marked to indicate the danger of high voltage.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the event of an abnormally low level of insulation resistance.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.5 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.6 All earthing impedances are to be connected to the hull. The connections to the hull are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.5.7 Where the **ELS** notation is to be assigned, earthed systems are not permitted unless they are isolated from the main generation and distribution system, e.g. through transformers and/or motor generator sets. *See also* 1.8.3.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplies by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A.

5.7.2 Lighting for the following spaces is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness. One of these circuits may be an emergency circuit provided it is normally energised.

- Spaces that are required to be lit for the safe working of the ship, such as control stations, normal working spaces, etc.
- Spaces where there may be a hazard due to movement of crew, embarked personnel and/or equipment, such as in corridors, working passage ways, stairways leading to boat decks, crew and embarked personnel rooms, etc.
- Spaces where there may be a hazard due to moving machinery and hot parts, such as in machinery spaces, workshops, large galleys, laundries, etc.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised in which case the arrangements are to comply with Section 3.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3. *See also* Section 17.

5.7.5 Lighting of unattended spaces, such as store spaces, is to be controlled by multi-pole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.7.6 For the design of lighting systems in magazines, weapon storage compartments and other dangerous spaces refer to Vol 1, Pt 4, Ch 1,6.8 and Vol 2, Pt 10, Ch 1,13.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.5.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.11.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

■ *Section 6* System design – Protection

6.1 General

6.1.1 Installations are to be protected against overcurrents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;

(b) elimination of the fault to reduce damage to the system and hazard of fire.

(c) uninterrupted electrical supply during normal operation of the system including motor starting and similar transient over-current conditions.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested.

6.1.4 Short circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.5 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.6 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments.

6.1.7 Protection may be omitted from the following:
(a) Engine starting battery circuits.
(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.8 Short circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition and where the cabling or wiring is installed in a manner such as to minimise the risk of short circuit.

6.1.9 Overload protection may be omitted from the following:
(a) one line of circuits of the insulated type;
(b) circuits supplying equipment incapable of being over-loaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in 6.5 and 6.6 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:
(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;
(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:
(a) for alternating current systems at the main switchboard:
10 x f.l.c. (rated full load current) for each generator thatmay be connected, or, if the subtransient direct axis reactance, X”d , of each generator is known,
$\frac{f.l.c}{X''d(p.u.)}$ for
each generator, and 3 x f.l.c. for motors simultaneously in service.
The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).
(b) battery-fed direct current systems at the battery terminals:
(i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours; or
(ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 Ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours; and
(iii) 6 x f.l.c. for motors simultaneously in service (if applicable).

6.3 Protection against overload

6.3.1 The characteristics of protective devices provided for overload protection are to ensure that cabling and electrical machinery is protected against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 600269-1, of type ‘a’) are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation;
(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;
(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker; and
(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded; and
(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover; a fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically sufficient load to reduce the load when the generator(s) is/are overloaded. Appropriate time delays are to be provided in these load reduction arrangements.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 The load management of power systems supplying electric propulsion motors is to satisfy the requirements of 15.2.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multipole circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. Motors for services essential for the safety and propulsion of the ship and which are duplicated are to be provided with arrangements to start the standby motor and disconnect the faulty motor. Such motors may have an overload alarm instead of overload protection. The actions to start the standby motor and disconnect the faulty motor may be carried out by suitably trained personnel but in ships with **UMS** notation the arrangements are to be automatic.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short circuit protection.

6.11.4 The characteristics of the arrangements for overload protection of motors are to be selected in relation to both the starting and normal rated conditions that are to include any load factors of intermittent service motors.

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

■ *Section 7*
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards
amended where necessary for ambient temperature and other
environmental conditions:

(a) IEC 60439: Low voltage switchgear and control gear assemblies;
(b) IEC 60298: AC Metal enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 72.5 kV;
(c) IEC 60466: AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV;
(d) IEC 60255: *Electrical Relays*;
(e) an acceptable and relevant National Standard; or
(f) specialised acceptable and relevant Naval Standards.

In addition, the requirements of 7.2 to 7.19 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidisation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 For bare conductors, where no precautions are taken against surface oxidisation, the temperature rise limit at rated normal current is not to exceed 45°C. Where suitable precautions are taken against surface oxidisation, e.g. by using silver, nickel or tin coated terminations, a temperature rise limit not exceeding 60°C may be permitted. Where the busbar temperature rises are above 45°C it is to be ensured that there is no adverse effect on equipment adjacent to and/or connected to the busbars and that the temperature rise limits of any materials in contact with the busbars are not exceeded. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: Low voltage switchgear and Control gear Part 2: circuit breakers; or
(b) IEC 62271-100: *High-voltage switchgear and control gear – Pt 100: High-voltage alternating-current circuit-breakers;*
(c) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.3 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60470: High-voltage alternating current contactors; or
(b) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are
to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 1.7.1.

Table 1.7.1 Minimum clearance distances

Rated Voltage V	Minimum clearance (mm) between phases and earth		Minimum clearance (mm) between phases
	Earthed neutral	insulated neutral	
≤660	16	19	19
1000	25	25	25
3600	55	55	55
7200	70	100	100
12000	85	140	140
15000	100	165	165

7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 1.7.1.

7.5.3 Creepage distances cannot be accurately specified as they depend upon the insulating material, dust deposits, humidity, etc. They are to be not less than the clearance distances given in Table 1.7.1, or less than 16 mm per 1000 V (rated voltage), whichever is the greater.

7.6 Degree of protections

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure, *see* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60269: Low-voltage fuses; or
(b) IEC 60282-1: High voltage fuses Part 1: Current-limiting fuses; or
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrails or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is to be provided with at least one volt-meter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured.

7.12 Instruments scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 *See* Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components is to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as is practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions. *See* Pt 7, Ch 2,2.8.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault.

7.17 Switchboard auxiliary power supplies

7.17.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer, *see also* 1.3.2.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer, *see also* 1.3.2.

7.18.2 A high voltage test, *see* Section 20.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with an appropriate standard, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors are to comply with one of the following standards, amended as necessary for ambient temperature and other environmental conditions:

(a) IEC 600947-3: Low voltage switchgear and control gear Part 3: Switches, disconnectors and fuse combination units.
(b) IEC 62271-102: High-voltage switchgear and control gear – Pt 102: High-voltage alternating current disconnectors and earthing switches;
(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8*
Rotating machines

8.1 General requirements

8.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this section. In addition, military aspects for shock are to be defined as required by Pt 1, Ch 2,4.8.

8.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 8.8.

8.1.3 For rotating machines of 100 kW and over intended for essential services, shaft materials are to comply with Vol 1, Part 2.

8.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

8.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034 Rotating electrical machines Part 14.

8.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum ship inclinations defined by 1.9 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

8.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

8.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short circuit at their terminals without damage.

8.1.9 AC generators and motors for electrical propulsion systems are to have at least one embedded temperature detector (ETD) in each phase of the machine winding in locations which may be subjected to the highest temperature. Where there are two coil sides per slot the ETD's are to be located between the insulated coil sides in the slot, *see* 15.1.3.

8.1.10 The adverse effect of voltage stresses on the winding insulation caused by the operation of switching devices is to be taken into account in the specification, design and installation of inverter fed induction motors.

Table 1.8.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	– –	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	– 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	–	–	80	100	125
(b) Stationary field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings						
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 1.8.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.8.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETD's are located between coil sides in the slot.

8.2 Rating

8.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 8.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 8.3.

8.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

8.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

8.3 Temperature rise

8.3.1 The limits of temperature rise specified in Table 1.8.1, are based on the cooling air temperature and cooling water temperature given in 1.8.

8.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.8 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

8.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.8 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.8 up to a maximum of 15ºC.

8.4 Generator control

8.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distribution system should there be a failure of the voltage regulating system resulting in a high voltage.

8.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

8.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds. In the absence of precise data the applied load is to be not less than 50 per cent of rated kVA at a power factor not greater than 0,4.

8.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off. When a generator is supplying any load between 25 per cent and 100 per cent of rated load, and a load equal to 25 per cent rated load at a power factor of 0.8 is suddenly removed, the transient voltage rise at the terminals of the generator is not to exceed 7,5 per cent.

8.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any longer time delay which may be provided by a tripping device for discrimination purposes. The generator terminal voltage is not to exceed 120 per cent of the rated voltage when the short circuit is removed.

8.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

8.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machines.

8.4.8 For **ELS** notation, *see* 1.8.5.

8.5 Overloads

8.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators.** An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

(b) **Motors.** At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

(c) **Propulsion machines.** The overload tests for propulsion machines will be specially considered for each installation.

8.6 Machine enclosure

8.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

8.7 Direct current machines

8.7.1 The final running position of brushgear is not to give rise to excessive sparking and is to be clearly and permanently marked.

8.8 Survey and testing

8.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded, *see also* 1.3.2.

8.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

8.8.3 A high voltage test, in accordance with Section 20, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

8.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

$V_{peak} = 2,45V$

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of interturn insulation will be considered.

Section 9
Converter equipment

9.1 Transformers

9.1.1 Paragraphs 9.1.2 to 9.1.12 apply to transformers rated for 5 kVA upwards.

9.1.2 Transformers are to comply with the requirements of IEC 60076 Power transformers, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

9.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.8, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
insulation of Class A – 50ºC
insulation of Class E – 60ºC
insulation of Class B – 70ºC
insulation of Class F – 90ºC
insulation of Class H – 110ºC

(b) For liquid filled transformers:
50ºC – where air provides cooling of the fluid
65ºC – where water provides cooling of the fluid.

9.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

9.1.6 The inherent regulation of transformers at their rated output is to be such that the total percentage voltage drop to any point in the installation does not exceed that allowed by 1.7.2(a).

9.1.7 Transformers, except those for motor starting, are to be double wound.

9.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

9.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

9.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

9.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

9.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also* 1.3.2:
(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests; and
(c) temperature rise test on one transformer of each size and type.

9.2 Semiconductor equipment

9.2.1 The requirements of 9.2.2 to 9.2.17 apply to semiconductor equipment rated for 5 kW upwards.

9.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.8.

9.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

9.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

9.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

9.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

9.2.7 Cooling fluids are to be non-toxic and of low flammability.

9.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

9.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

9.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

9.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced in to the ships electrical system are within the limits of 1.7.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation. Converter equipment cables may carry high frequency currents that can cause interference. These cables are to be kept as short as possible and installed as far away as possible from sensitive signal cables.

9.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

9.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

9.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

9.2.15 Transformers, reactors, capacitors and other circuit devices associated with convertor equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

9.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.7.

9.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

9.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 20.1, a temperature rise test, where practical, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Where a temperature rise test cannot be carried out at the manufacturer's works, it is to form part of the sea trials programme. Details of tests are to be submitted for consideration when required, *see also* 1.3.2.

Section 10 Electric cables and busbar trunking systems (busways)

10.1 General

10.1.1 The requirements of 10.1 to 10.15 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 10.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

10.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 1.10.1 or a relevant standard acceptable to the Naval Authority.

Table 1.10.1 Electric cables

Application	IEC Publication	Title
General constructional and testing requirements	60092–350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092–353	Single and multicore non- radial field power cables with extruded solid insulation for rated voltages 1 kV and 3 kV
Fixed power circuits	60092–354	Single and three-core power cables with extruded solid insulation for rated voltages 6 kV, 10 kV and 15 kV
Instrumentation, control and communication circuits up to 60 V	60092–375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092–376	Shipboard multicore cables for control circuits
Mineral insulated	600702	Mineral insulated cables with a rated voltage not exceeding 750 V

10.1.3 Where increased flexibility is required due to confines of space, cables having Class 5 stranded conductors in accordance with *IEC 60228 Conductors of insulated cables* may be accepted provided 10.1.2 is otherwise complied with. Provided that the adequate flexibility of the finished cable is assured, conductors of nominal cross-sectional area 2,5 mm^2 and less need not be stranded.

10.1.4 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant standard.

10.1.5 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

10.2 Testing

10.2.1 Routine tests, consisting of at least:
(a) measurement of electrical resistance of conductors;
(b) high voltage test (*see also* Section 20);
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer, *see also* 1.3.3.

10.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 10.1.2 and a test report issued by the manufacturer.

10.3 Voltage rating

10.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

10.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

10.4 Operating temperature

10.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10ºC higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

10.4.2 The maximum rated conductor temperatures for normal and short circuit operation, for the insulating materials included within the standards referred to in 10.1.2 is not to exceed the values stated in Table 1.10.2.

10.4.3 Electric cables constructed of an insulating material not included in Table 1.10.2 are to be rated in accordance with the National Standard chosen in compliance with 10.1.2. *See also* 1.14.4.

Table 1.10.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short circuit
Thermoplastics:		
– Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	60	150
– Based upon polyethylene	60	130
Elastomeric or thermosettings:		
– Based upon ethylene propylene rubber or similar (EPM or EPDM)	85	250
– Based upon chemically crosslinked polyethylene	85	250
– Based upon silicon rubber	95	To be submitted
Mineral:	95	To be submitted

10.5 Construction

10.5.1 Electric cables are to be at least of a flame-retardant, low smoke, halogen free type. Compliance with IEC 60332-1: *Tests on a single vertical insulated wire or cable*, IEC 61034: *Measurements of smoke density of electric cables burning under defined conditions*, IEC 60754: *Tests on gases evolved during combustion of materials from cables* will be acceptable. Where cables are installed in bunches, the requirements of 10.8.8 are to be satisfied.

10.5.2 Exemption from the requirements of 10.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

10.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to comply with the performance requirements of IEC 60331: *Fire characteristics of electric cables*.

10.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions. Where cables are required to remain operational when immersed in water, oil or other substances for prolonged periods, the cable sheathing is to be demonstrably suitable for this environment. Evidence of immersion testing is to be submitted for consideration on request.

10.5.5 Electric cables where it is required that their construction includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion.

10.5.6 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

10.5.7 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

10.5.8 All high voltage electric cables are to be readily identified by suitable marking.

10.6 Conductor size

10.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 10.7 may be applied as required.

10.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short circuit conditions, the maximum rated conductor temperature for short circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short circuit current.

10.6.3 The cable current ratings given in Tables 1.10.3 and 1.10.4 are based on the maximum rated conductor temperatures given in Table 1.10.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short circuit temperature limits, other than those given in Table 1.10.4, may be calculated using the method in IEC 60724, *Guide to the short circuit temperature limits of electric cables* or an acceptable and relevant National Standard.

10.6.4 The cross sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.7 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

10.6.5 The size of earth conductors is to comply with 1.11.7.

10.6.6 The cross sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cables maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service (*see* 10.7.4).

Table 1.10.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross section	Continuous r.m.s current rating, in amperes								
	Thermoplastic,PVC, PE			EP rubber and crosslinked PE			Silicon rubber or mineral		
	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core
0,75	6	5	4	13	11	9	17	14	12
1	8	7	6	16	14	11	20	17	14
1,25	10	8	7	18	15	13	23	19	16
1,5	12	10	8	20	17	14	24	20	17
2	13	11	9	25	21	17	31	26	21
2,5	17	14	12	28	24	20	32	27	22
3,5	21	18	14	35	30	24	39	33	27
4	22	19	15	38	32	27	42	36	29
5,5	27	23	19	46	39	32	52	44	36
6	29	26	20	48	41	34	55	47	39
8	35	30	24	59	50	41	66	56	46
10	40	34	28	67	57	47	75	64	53
14	49	42	34	83	71	58	94	80	66
16	54	46	38	90	77	63	100	85	70
22	66	56	46	110	93	77	124	105	87
25	71	60	50	120	102	84	135	115	95
30	80	68	56	135	115	94	151	128	106
35	87	74	61	145	123	102	165	140	116
38	92	78	64	155	132	108	175	149	122
50	105	89	74	185	153	126	200	175	140
60	123	104	86	205	174	143	233	198	163
70	135	115	95	225	191	158	255	217	179
80	147	125	103	245	208	171	278	236	195
95	165	140	116	275	234	193	310	264	217
100	169	144	118	285	242	199	320	272	224
120	190	162	133	320	272	224	360	306	252
125	194	165	134	325	280	230	368	313	258
150	220	187	154	365	310	256	410	349	287
185	250	213	175	415	353	291	470	400	329
200	260	221	182	440	375	305	494	420	346
240	290	247	203	490	417	343	570	485	400
300	335	285	235	560	476	392	660	560	460

Table 1.10.4 Electric cable current ratings, r.m.s. short circuit current

Nominal cross section	Fault current at 250°C duration			Fault current at 150°C duration			Fault current at 130°C duration		
	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA	1,0 sec. kA	0,5 sec. kA	0,1 sec. kA
1	0,1	0,2	0,5	0,1	0,2	0,4	0,1	0,2	0,3
1,5	0,2	0,3	0,7	0,2	0,3	0,5	0,2	0,3	0,5
2,5	0,4	0,5	1,1	0,3	0,4	0,9	0,3	0,4	0,8
4	0,6	0,8	1,8	0,5	0,7	1,5	0,4	0,6	1,3
6	0,9	1,2	2,8	0,7	1,0	2,2	0,6	0,9	2,0
10	1,5	2,1	4,6	1,2	1,6	3,7	1,0	1,5	3,3
16	2,3	3,3	7,4	1,9	2,6	5,9	1,7	2,4	5,3
25	3,6	5,2	12	2,9	4,1	9,2	2,6	3,7	8,2
35	5,1	7,2	16	4,1	5,8	13	3,6	5,2	12
50	7,3	10	23	5,8	8,2	18	5,2	7,4	16
70	10	14	32	8,2	12	26	7,3	10	23
95	14	20	44	11	16	35	9,9	14	31
120	17	25	55	14	20	44	13	18	40
150	22	31	69	17	25	55	16	22	49
185	27	38	85	22	31	68	19	27	61
240	35	49	110	28	40	89	25	35	79
300	44	62	140	35	50	110	31	44	100

10.7 Correction factors for cable current rating

10.7.1 The correction factors of 10.7.2 to 10.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

10.7.2 **Bunching of cables**. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

10.7.3 **Ambient temperature**. The current ratings of Table 1.10.3 are based on an ambient temperature of 45ºC. For other values of ambient temperature the correction factors shown in Table 1.10.5 are to be applied.

10.7.4 **Short time duty**. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant, T in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-load less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

where

t_p = the intermittent period, in minutes, i.e. the total period of load and no-load before the cycle is repeated

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current in minutes

10.7.5 **Diversity**. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

10.8 Installation of electric cables

10.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

10.8.2 The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 1.10.6.

Table 1.10.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
PVC, Polyethylene	1,29	1,15	1,00	0,82	—	—	—	—	—	—	—
EPR, XLPE	1,12	1,06	1,00	0,94	0,87	0,79	0,71	0,61	0,50	—	—
Mineral, Silicon rub-	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 1.10.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	20*D*
– multicore	Any	Any	15*D*

10.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

10.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

10.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

10.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

10.8.7 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

10.8.8 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332-3, category A/F provided that, in addition, there is no shedding of flaming droplets of sheath or insulation material and that they are installed to the same configuration(s) as used in the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures are taken to ensure that an equivalent limit of fire propagation will be achieved for the configuration(s) used. Particular attention is to be given to cables in vertical runs in trunks and other restricted spaces. In addition, cables which comply with the requirements of IEC 60332-3 are also required to meet the requirements of IEC 60332-1.

10.8.9 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

10.8.10 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

10.8.11 All metal coverings of electric cables are to be earthed in accordance with 1.11.

10.8.12 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

10.8.13 High voltage electric cables are not to be run in the open through accommodation spaces.

10.8.14 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

10.8.15 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary the cables are to be protected in accordance with the requirements of 10.9.

10.8.16 Electric cables with the exception of those for portable appliances and those installed in protective casings are to be fixed securely in accordance with the requirements of 10.10.

10.8.17 Where electric cables penetrate bulkheads and decks the requirements of 10.11 are to be complied with.

10.8.18 Where electric cables are installed in protective casings the requirements of 10.12 are to be complied with.

10.8.19 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 10.13 are to be complied with. *See also* 10.5.6.

10.9 Mechanical protection of cables

10.9.1 Electric cables exposed to risk of mechanical damage are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

10.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as hangers, storage spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the ship's structure affords adequate protection.

10.9.3 Non-metallic protective casings and fixings are to be flame retardant in accordance with the requirements of IEC 60092-101.

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10.9.4 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.11.

10.10 Cable support systems

10.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the ships' structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads etc., *see* 10.8.4.

10.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the ships' structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water. In addition, where applicable, military aspects for shock are to be defined as required by Pt 1, Ch 2,4.8.

10.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 1.10.7.

Table 1.10.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
exceeding	not exceeding		
mm	mm	mm	mm
–	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	–	400	450

10.10.4 Where the cables are laid on top of their support system, the spacing of the clips, straps, etc. securing the cables may be increased beyond the spacing given in Table 1.10.7, but should take account of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to sea-water impingement.

10.10.5 Where the cable support system or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided, such that, in the event of a fire or failure, the cable support system and the cables affixed to it are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

10.10.6 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short circuit current.

10.11 Penetration of bulkheads and decks by cables

10.11.1 Where electric cables pass through watertight, fire insulated or gas tight bulkheads or decks separating dangerous zones or spaces from non-dangerous zones or spaces, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

10.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

10.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

10.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

10.12 Installation of electric cables in protective casings

10.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

10.12.2 When protective casings are secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m.

10.12.3 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

10.12.4 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 10.8.2.

10.12.5 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

10.12.6 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

10.12.7 Expansion joints are to be provided in protective casings where necessary.

10.12.8 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

10.13 Single core electric cables for alternating current

10.13.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

10.13.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

10.13.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

10.13.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

10.13.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

10.14 Electric cable ends

10.14.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see* 1.10.6), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent ‘whiskering’ of the strands.

10.14.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

10.14.3 Soldered sockets may be used in conjunction with non corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160ºC.

10.14.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

10.14.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

10.14.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating or corrosion.

10.14.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

10.14.8 Cable terminations are to be suitable for the operating voltages and currents and may be of the screw-clamp or spring-clamp type or plug and socket connectors.

10.15 Joints and branch circuits in cable systems

10.15.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties or fire resisting properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

10.15.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

10.15.3 Cables of a fire resistant type (*see* 10.5.3) are to be installed so that they are continuous throughout their length without any joints or tappings.

10.16 Busbar trunking systems (bustrunks)

10.16.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 10.16.2 to 10.16.6, in addition to the applicable requirements in Section 7.

10.16.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

10.16.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

10.16.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.9 for essential electrical equipment.

10.16.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the ship's structure.

10.16.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

10.17 Cable segregation

10.17.1 To reduce mutual interference, cables with different signal levels are to be grouped in accordance with Table 1.10.8 and installed with the separation distances as shown in Table 1.10.9.

Table 1.10.8 Cable segregation groups

Criteria	Signal level		Group	Application
	LF/DC	HF Pulse		
Very sensitive	1 mV	1 µV	A	Receiver antenna cables Television antenna cables (RX) Infrared receiver cables Sonar/sounder receiving cables Radio MF receiver cables Radar MF receiver cables Dynamic microphone input Servo amplifier input (asymmetric and high impedance)
Sensitive	100 mV	10 µV	B	Voltage, frequency and phase dependent signal cables Reference voltage and synchro system cables (400/1100Hz) Servo amplifier input cables (symmetric) Analogue and digital cables (symmetric and low voltage signal) M and P lines, sound powered telephone cables
Low sensitivity, low interference	24 V		C	Power supply cables High power cables Telephone, telex, loudspeaker and signal key cables Press to talk cables Start/stop signalling cables
Interference	440 V	3 V	D	Synchronisation cables Video cables Strobe cables Marker cables Pulse cables (low power) Control cables from wide band amplifiers Digital signal cables (low level or asymmetrical and high level) High power synchro cables
High interference		30 V	E	Transmit antenna cables Main electromotor cables Modulator pulsed cables Pulse cables for high power Echo sounder transmit and receiver cables
Very sensitive with high interference	1000 V	1000 V	F	Radio transmit and receive cables Transducer cables Echo sounder transmit and receiver cables
Immune, no interference			Z	Fibre optic cables

Table 1.10.9 Separation distances, mm

Group	A	B	C	D	E	F
A	—	50	100	150	200	200
B	50	—	50	100	150	100
C	100	50	—	50	100	100
D	150	100	50	—	50	100
E	200	150	100	50	—	200
F	200	100	100	100	200	—

■ *Section 11* Batteries

11.1 General requirements

11.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve regulated sealed type.

11.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

11.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

11.2 Construction

11.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

11.3 Location

11.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

11.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 11.3.1, or may be installed in a box within a well ventilated machinery or similar space.

11.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

11.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 11.3.1, 11.3.2 or 11.3.3.

11.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 11.5.10 and the charging requirements of 11.6.4 and 11.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

11.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

11.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

11.3.8 A permanent notice prohibiting naked lights and smoking is to be prominently displayed in all compartments containing vented type batteries.

11.4 Installation

11.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are safely secured.

11.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

11.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

11.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

11.5 Ventilation

11.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

11.5.2 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

11.5.3 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

11.5.4 Mechanical exhaust ventilation complying with 11.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW.

11.5.5 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 11.3.2 and 11.3.3 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

11.5.6 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

11.5.7 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic impellers are to be of an anti-static material.

11.5.8 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

11.5.9 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110 I n$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

11.5.10 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 11.5.9.

11.6 Charging facilities

11.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

11.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

11.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

11.6.4 Arrangements are to be fitted to automatically control the charging rate of valve regulated sealed batteries so as to prevent overcharging which may lead to an excessive evolution of gas. These arrangements are to take account of any Naval Authority requirements for prolonged operation under close down conditions.

11.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

11.7 Electrical equipment

11.7.1 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 11.3.1. Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

■ *Section 12*
Equipment – Heating, lighting and accessories

12.1 Heating and cooking equipment

12.1.1 The construction of heaters is to give a degree of protection according to IEC 600529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

12.1.2 Heating elements are to be suitably guarded.

12.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

12.2 Lighting – General

12.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

12.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

12.3 Incandescent lighting

12.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 1.12.1.

12.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

12.4 Fluorescent lighting

12.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 1.12.1.

Table 1.12.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	–	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	–
G5	250	13	–

12.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

12.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

12.5 Discharge lighting

12.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

12.6 Socket outlets and plugs

12.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30ºC. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

12.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

12.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

12.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

12.7 Enclosures

12.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 13*
Electrical equipment for the use in explosive gas atmospheres or in the presence of combustible dusts

13.1 General

13.1.1 The installation of electrical equipment in areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the ship.

13.1.2 For design guidance on electrical systems in magazines, refer to Vol 1, Pt 4, Ch 1,6.8.

13.2 Selection of equipment

13.2.1 When apparatus is to be installed in areas where an explosive gas atmosphere may be present, unless permitted otherwise by 13.2.2, it is to be of a 'safe type', as listed below, certified or approved by a competent authority for the gases encountered. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe – Ex 'i'
Increased safety – Ex 'e'
Flameproof – Ex 'd'
Pressurised enclosure – Ex 'p'
Powder filled – Ex 'q'
Encapsulated – Ex 'm'
Special – Ex 's'.

13.2.2 Consideration may be given to the use of equipment of the following types:

(a) equipment such as control panels, protected by purging and pressurisation and capable of being verified by inspection as meeting the requirements of IEC 60079-2;
(b) simple non-energy-storing apparatus having negligible surface temperature rise in normal operation, such as limit switches, strain gauges, etc, incorporated in intrinsically-safe circuits;

(c) radio aerials having robust construction, meeting the relevant requirements of IEC 60079-15. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment;

(d) electrical apparatus with type of protection 'n' or 'N' provided it is in a well ventilated area on open deck and not within 3 m of any flammable gas or vapour outlet.

13.2.3 Where apparatus is to be installed in areas where combustible dusts may be present in quantities sufficient to create an explosive atmosphere, it is, when practicable, to be of a type certified or approved by a competent authority for the dusts and additionally any explosive gases encountered.

13.2.4 Electrical equipment for use in combustible dust atmospheres is to be so designed and installed as to minimise the accumulation of dust which may interfere with the safe dissipation of heat from the enclosure.

13.2.5 Where equipment certified for combustible dusts is not available, consideration will be given to the use of apparatus complying as a minimum, with the following requirements provided no explosive gases will be present:

(a) the enclosure is to be at least dust protected (IP5X) having, when type tested, an ingress of fine dust within the enclosure not exceeding 10 g per m^3 of free air space; and

(b) the surface temperature of the apparatus, under the most onerous combination of normal operating conditions, but in the absence of a dust layer, is to be at least 10ºC below the auto-ignition temperature of the dusts encountered; or

(c) the equipment is to be certified intrinsically-safe having a temperature classification ensuring compliance with (b); or

(d) pressurised and operated in accordance with procedures ensuring, prior to its re-energisation, the absence of dust within the enclosure following loss of pressurisation and consequent shutdown, and having surface temperature complying with (b); or

(e) simple apparatus included in intrinsically-safe circuits or radio aerials, complying with 13.2.2(b) or (c) respectively.

13.3 Installation of electrical equipment

13.3.1 The method of installation and application of safe type equipment is to be in accordance with IEC 600 79-14, or the national code of practice relevant to the standard to which the equipment has been certified. Any special requirements laid down by the equipment certification documentation are also to be observed. The ambient temperature range for which the apparatus is certified, is to be taken to be –20ºC to 40ºC, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases and dusts encountered.

13.3.2 All switches and protective devices from which equipment located in dangerous zones or spaces is supplied are to interrupt all poles or phases and, where practicable are to be located in a non-hazardous zone or space. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

13.4 Dangerous zones and spaces

13.4.1 For dangerous zones or spaces and sources of hazard for naval ships, the following principles are to apply in general.

13.4.2 A dangerous zone or space may arise from the presence of any of the following:

(a) spaces or tanks containing either:
 (i) flammable liquid having a flashpoint (closed-cup test), not exceeding 60ºC;
 (ii) flammable liquid having a flashpoint exceeding 60ºC, heated or raised by ambient conditions to a temperature within 15ºC of its flashpoint;
 (iii) flammable gas.

(b) piping systems or equipment containing fluid defined by (a) and having flanged joints or glands or other openings through which leakage of fluid may occur under normal operating conditions;

(c) spaces containing solids, liable to release flammable gas and/or combustible dust;

(d) piping systems or equipment associated with processes (such as battery charging or electrochlorination) generating flammable gas as a by-product and having openings from which the gas may escape under normal operating conditions;

(e) piping systems or equivalent containing flammable liquids not defined by (a), having flanged joints, glands or other openings through which leakage of fluid in the form of a mist or fine spray may occur under normal operating conditions.

13.4.3 The following zones or spaces are regarded as dangerous:

(a) the interiors of those spaces, tanks, piping systems and equipment defined by 13.4.2(a), (b) and (c);

(b) spaces separated by a single bulkhead or deck from a substance defined by 13.4.2(a);

(c) enclosed or semi-enclosed spaces containing pipework or equipment defined by 13.4.2(b) and (d);

(d) enclosed or semi-enclosed spaces with direct opening into a dangerous space or zone;

(e) zones within a 3 m radius of ventilation inlets or outlets, hatches or doorways or other openings into dangerous spaces, or within 3 m of the ventilation outlets of spaces regarded by 13.6 as open areas and which contain the pipework or equipment defined by 13.4.2(b); where the hazard results from flammable gas or vapour having a density relative to that of air of more than 0,75, the dangerous zone is considered to extend vertically down-ward to solid deck, or for a distance of 9m, whichever is the lesser;

(f) zones within a 3 m radius of flanged joints, or glands or other openings defined by 13.4.2(b); in the case of gas or vapour having a relative density of more than 0,75, the dangerous zone is considered to extend vertically downwards as described under (e);
(g) zones within a 1,5 m radius of the ventilation outlets of spaces regarded as open areas containing items defined under 13.4.2(d);
(h) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by 13.4.2(d) and (e);
(j) zones within a 3 m radius of bounds or barriers intended to contain spillage of liquids defined by 13.4.2(a).

13.5 Semi-enclosed spaces

13.5.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

13.6 Ventilation

13.6.1 Where an enclosed or semi-enclosed space is provided with mechanical ventilation ensuring at least 12 air changes/hour, and leaving no areas of stagnant air, it may be regarded in consideration of dangerous zones as would otherwise be defined by 13.4.3(c) and (d), as an open area.

13.6.2 Where the rate of ventilation air flow, in relation to the maximum rate of release of flammable substances reasonably to be expected under normal conditions, is sufficient to prevent the concentration of flammable substances approaching their lower explosive limit, consideration may be given to regarding as non-dangerous, the space, ventilation and other openings into it, and the zone around the equipment contained within.

13.7 Pressurisation

13.7.1 A space having access to a dangerous space or zone as defined under 13.4.3(c) to (j) may be regarded as non-dangerous if fulfilling all the following conditions:
(a) access is by means of an air-lock, having gas-tight steel doors, the inner of which as a minimum, is self-closing without any hold-back arrangement;
(b) it is maintained at an overpressure relative to the external hazardous area by ventilation from a non-dangerous area;
(c) the relative air pressure within the space is continuously monitored and, so arranged, that in the event of loss of overpressure an alarm is given and the electrical supply to all equipment not of a safe type is automatically disconnected. Where the shut-down of equipment could introduce a hazard, an alarm may be given, in lieu of shutdown, upon loss of overpressure, and a means of disconnection of non-safe type electrical equipment, capable of being controlled from a manned station, provided in conjunction with an agreed operational procedure; where the means of disconnection is located within the space then it is to be effected by equipment of a safe type;
(d) any electrical equipment required to operate upon loss of overpressure, lighting fittings (*see* 5.7.4) and equipment within the air-lock, is to be of a safe type;
(e) means are to be provided to prevent electrical equipment, other than of a safe type, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the capacity of the space.

13.8 Cable and cable installation

13.8.1 In addition to the requirements of Section 10, cables for circuits that are not intrinsically safe, which are located in dangerous zones or spaces, or which may be exposed to oil, vapour or gas, are to be either:
(a) mineral insulated with copper sheath; or
(b) armoured or braided for earth detection.

13.8.2 Armouring, braiding and other metal coverings of cables installed in dangerous zones or spaces are to be effectively earthed at least at both ends, *see* 1.11.3.

13.8.3 Where there is risk of intermittent contact between armour and exposed metalwork, non-metallic impervious sheath is to be applied over metallic armour of cables.

13.8.4 Cables associated with intrinsically-safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically-safe circuits, e.g. neither installed in the same protective casing nor secured by the same fixing clip.

13.9 Special requirements for ships with spaces for carrying vehicles, helicopters and aircraft, with fuel in their tanks

13.9.1 Ships with closed spaces carrying vehicles, helicopter and aircraft with fuel having a flashpoint not exceeding 60ºC:
(a) except where exempted by (b) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a safe type;
(b) where the ventilation system required by the Naval Authority is arranged to operate continuously and is sufficient to provide at least ten air changes per hour, whenever vehicles are on board, above a height of 45 cm from the vehicle deck, or any platform on which vehicles are carried, electrical equipment having an enclosure of ingress protection rating of at least IP 55 may be accepted as an alternative to that of a safe type;
(c) all electrical circuits terminating in the space are to be provided with multi-pole linked isolating switches located outside the space concerned. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

Section 14
Navigation and manoeuvring systems

14.1 Steering gear

14.1.1 The requirements of 14.1.2 to 14.1.7 are to be read in conjunction with those in Pt 6, Ch 1.7.

14.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard, *see also* Pt 6, Ch 1,7.

14.1.3 The main and auxiliary steering gear motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

14.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering gear.

14.1.5 Only short circuit protection is to be provided for each main and auxiliary steering gear motor circuit.

14.1.6 Where agreed by the Naval Authority, in ships of category NS3, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 14.1.5 for such a motor primarily intended for other services.

14.1.7 Each main and auxiliary steering gear electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

14.2 Thruster systems for steering

14.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven the requirements of Pt 4, Ch 3,7 are to be complied with.

14.3 Thruster systems for dynamic positioning

14.3.1 For ships having a **DP** notation the requirements of Vol 3, Pt 1, Ch 3 are to be complied with.

14.4 Thruster systems for manoeuvring

14.4.1 Where a thruster unit is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

14.4.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the ship, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

14.4.3 The thruster unit electric motor is not to be disconnected as part of a load management switching operation.

14.5 Navigation lights

14.5.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected to the emergency source of electrical power in compliance with, 3.2.5(c) and 3.2.7(a). Provision is to be made on the navigation bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

14.5.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

14.5.3 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to small vessels.

14.5.4 Where there is no dedicated emergency source of electrical power because there are two or more main electrical power sources as permitted by 3.1.3, the navigation light panel is to be connected to at least two sources of power with arrangements to transfer between the two sources.

14.5.5 Naval Authority requirements including the use of battery power navigation lights are to be complied with and may be accepted as an alternative to the above.

14.6 Navigational aids

14.6.1 Navigational aids as required by the Naval Authority are to be fed from the emergency source of electrical power. (*See also* 3.2.5(c)(ii) and 3.3.5(d)(ii)).

14.6.2 Ships having a notation **NAV 1** navigational aids are to have an alternative supply fed from the main source of electrical power, independent of the emergency switchboard, with automatic change-over facilities.

■ *Section 15* Electric propulsion

15.1 General

15.1.1 Where the arrangements permit a propulsion motor to be connected to a generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

15.1.2 The ventilation and cooling systems for electrical propulsion equipment are to be provided with monitoring devices arranged to operate an alarm if the temperature of the heated cooling medium exceeds a predetermined safe value.

15.1.3 The embedded temperature detectors required by 8.1.9 are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.

15.2 Power requirements

15.2.1 The propulsion system is to have sufficient power for manoeuvring the vessel and for going astern. With the ship travelling at her maximum service speed the propulsion equipment is to be capable of stopping and reversing the ship in an agreed time.

15.2.2 The propulsion system is to have adequate torque and power margins for all operating conditions including manoeuvring and rough weather with due regard to propeller and ship characteristics.

15.2.3 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a central power generation plant which serves both propulsion and ship service loads.

15.2.4 Where propulsion power is derived from a central, common, power plant the control system is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in propulsion power if necessary.

15.2.5 Where a central power generation system is employed the number and rating of generator sets is to be such that with one set out of action the remaining sets are capable of providing all essential and normal ship service loads whilst maintaining an effective level of propulsion power.

15.2.6 Where, in a central power generation system, the electrical power requirements are normally supplied by two or more generating sets operating in parallel, on sudden loss of power from one set, the rating of the remaining set(s) in service is to be sufficient to ensure uninterrupted operation of essential services and an effective level of propulsion power.

15.3 Propulsion control

15.3.1 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action.

15.3.2 Control of propeller speed, and/or pitch, from zero to full ahead or astern is to be provided.

15.3.3 The control system is to ensure that there is no dangerous overspeeding of propulsion motors upon loss of load.

15.3.4 Interlocks are to be provided in the control system to ensure that ahead and astern circuits are not energised simultaneously.

15.3.5 Any single fault in either the propulsion machine excitation or power distribution systems is not to result in a total loss of propulsion power.

15.3.6 Control stations for the propulsion system are to satisfy the requirements of Pt 9, Ch 1.

15.3.7 Each control station is to be provided with emergency stops for propulsion motors. The emergency stop is to be independent of the normal control system.

15.3.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.

15.3.9 Alternative means of operation, independent of any remote system, are to be provided to permit effective control of the propulsion equipment for all intended functional requirements. The alternative control facility is to include all necessary protection and power limitation features.

15.3.10 The propulsion control may be in analogue or digital form, which is to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements listed above. A quality plan giving evidence of compliance with this requirement is to be submitted when requested.

15.4 Protection of propulsion system

15.4.1 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to plant.

15.4.2 The main propulsion circuits are to be provided with means for detecting earth faults. Where the fault current flowing is liable to cause damage to the electrical equipment there are to be arrangements for interrupting the current.

15.4.3 For the protection of electrical equipment and cables against overvoltages means are to be provided for limiting the induced voltage when field windings, and other inductive circuits are opened. Protective resistors and devices are to be sized to cater for the likely extreme operating conditions.

15.4.4 Where, on stopping or reversing the propeller, regenerated energy is produced by the propulsion motor this is not to cause a dangerous increase of speed in the prime mover or a dangerous overvoltage condition on the supply system. Where a central power generation system is used then the voltage and frequency fluctuations are not to exceed the limits given in 1.7.

15.5 Instruments

15.5.1 The main control station is to be provided with indicating instruments or other means of continuously monitoring the following:

(a) a.c. systems
  - (i) The line current and excitation current of each generator and propulsion motor; and for each generator, the voltage, power and frequency.
  - (ii) The winding and cooling system temperature of each generator and propulsion motor.

(b) d.c. systems
  - (i) The armature voltage and current for each generator and propulsion motor and the current in each excitation circuit.

15.5.2 Each control station is to be provided with instruments to indicate:

(a) propeller speed;

(b) direction of rotation for a fixed pitch propeller or pitch position for a controllable pitch propeller;

(c) visual indication of power limitation.

Section 16
Fire safety systems

16.1 Fire detection and alarm systems

16.1.1 Fire detection and alarm systems are to be provided with an emergency source of electrical power required by 3.2 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main fire control panel are to be provided. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.13 and 1.14.

16.1.2 For machinery spaces the requirements of Pt 9, Ch 1,2.8 are applicable.

16.1.3 The fire detection system within the accommodation spaces is, in addition to the requirements of Pt 9, Ch 1,2.8.4, 2.8.6, 2.8.8 and 2.8.10 to 2.8.14, to comply with 16.1.4 to 16.1.14.

16.1.4 The fire detection control panel is to be located on the navigating bridge or in the central control station and may form part of that panel specified in Pt 9, Ch 1,2.8.2.

16.1.5 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. This alarm sounder system need not be an integral part of the detection system.

16.1.6 Indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

16.1.7 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section.

16.1.8 Where the fire detection system does not include means of remotely identifying each detector individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

16.1.9 Where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the ship nor on more than one deck except when permitted by 16.1.14.

16.1.10 A section of fire detectors which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

16.1.11 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel.

16.1.12 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop each detector served by the circuit, may serve spaces on both sides of the ship and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers a control station or an accommodation space to include a machinery space of Category A.

16.1.13 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors will be isolated from the control panel. No section of detectors is in general to include more than 50 detectors.

16.1.14 A section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the ship nor on more than one deck, except that:

(a) a section of detectors may serve spaces on more than one deck if those spaces are located in either the fore and aft end of the ship or they constitute common spaces occupying several decks, i.e. personnel spaces, enclosed stairways, etc.

(b) in ships of less than 20 m in breadth, a section of detectors may serve spaces on both sides of the ship.

16.1.15 The wiring for each section of detectors in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop.

16.2 Automatic sprinkler system

16.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

16.2.2 Electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main switchboard and one from the emergency switchboard. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

16.2.3 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

16.2.4 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

16.2.5 For design guidance on electrical and fire protection systems in magazines, refer to Vol 1, Pt 4, Ch 1,6.8 and 9.

16.3 Fire pumps

16.3.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

16.3.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

16.4 Refrigerated liquid carbon dioxide systems

16.4.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

16.4.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

16.5 Fire safety stops

16.5.1 Means of stopping all ventilating fans, with manual reset, are to be provided, outside the spaces being served, at positions which will not readily be cut off in the event of a fire. The provisions for machinery spaces are to be independent of those for other spaces.

16.5.2 Machines driving forced and induced draught fans, and independently driven oil pumps for fuel, lubricating, hydraulic or refuelling oil, or other dangerous fluids are to be fitted with remote controls, with manual reset, situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

16.5.3 All power ventilation systems, machinery space ventilation, which is to be in accordance with 16.5.2 are to be fitted with master controls, with manual reset, so that all fans may be stopped, in the event of fire, from the central control station and from another position situated as far apart as is practicable. Off indication is to be provided for the ventilation fans at the central control station along with provisions to enable them to be reactivated.

16.5.4 Means of cutting off power to the galley, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

16.5.5 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire resistant type, *see* 10.5.3 and 5.2.1.

16.6 Fire doors

16.6.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. An alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.6.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

16.7 Fire dampers

16.7.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

16.7.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

16.8 Fire-extinguishing media release

16.8.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2, and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.13. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

16.8.2 The arrangements for accessing and activating the release of fire-extinguishing media are not to automatically shut off fuel oil, lubricating oil or hydraulic oil to machinery essential for the propulsion and the safety of the ship, *see* 1.5.1.

■ *Section 17*
Crew and embarked personnel emergency safety systems

17.1 Emergency lighting

17.1.1 For the purpose of this section emergency lighting, contingency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

17.1.2 A fire or other casualty in a space containing a source of electrical power associated transforming (or converting) equipment or switchboard serving lighting, is not to render inoperative both main lighting and emergency lighting.

17.1.3 The illuminance provided by any one lighting circuit is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 17.4.

17.1.4 The exit(s) from every main compartment occupied by crew and embarked personnel is to be continuously illuminated by an emergency lighting fitting.

17.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, (i.e. storage-rooms, cold rooms, etc.), or they are normally required to be extinguished for operational reasons, i.e. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to ships crew and embarked personnel with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions. Where 'darken ship' requirements are specified, switches may be installed in the circuits to emergency light fittings provided they are clearly identified.

17.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

17.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

17.1.8 A means of illumination is to be provided in passageways and manned compartments for a period of at least four hours in the event of a failure of all main and emergency lighting. The provision of lanterns that operate automatically from a self contained power source on failure of the main and emergency lighting systems is the minimum acceptable arrangement.

17.2 Emergency alarm system

17.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal is to comply with the *International Lifesaving-Saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.13 and 1.14.

17.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2 or 3.3 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13.

17.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone other than the zone in which the crew and embarked personnel address control station is located, will not interfere with the distribution in any other such zone.

17.2.4 There are to be segregated cable routes to crew and embarked personnel rooms, alleyways, stairways, and control stations, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any crew and embarked personnel rooms, alleyways, stairways, and control stations, be it at a reduced capacity.

17.2.5 Where the special alarm fitted to summon the crew–operated from the navigation bridge, or fire-control station, forms part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces

17.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 20.2.

17.3 Crew and embarked personnel address system

17.3.1 Crew and embarked personnel address systems are to comply with the *International Lifesaving-Saving Appliances (LSA) Code* and the requirements of this Section.

17.3.2 The crew and embarked personnel address system is to be provided with an emergency source of electrical power as required by 3.2 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the crew and embarked personnel address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.13 and 1.14.

17.3.3 The crew and embarked personnel address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in crew and embarked personnel rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

17.3.4 The crew and embarked personnel address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, other than the zone in which the crew and embarked personnel address control station is located, will not interfere with the distribution in any other such zone.

17.3.5 There are to be at least two cable routes sufficiently separated throughout their length to crew and embarked personnel rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any crew and embarked personnel rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

17.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the crew and embarked personnel address system, for tone signals.

17.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

17.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

17.3.9 Where the crew and embarked personnel address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 17.2:

(a) The emergency system is given automatic priority over any other system input.
(b) More than one device is provided for generating the sound signals for the emergency alarms.

17.3.10 Where more than one alarm is to be sounded through the crew and embarked personnel address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

17.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals and documented, *see* 20.2.

17.4 Escape route or low location lighting (LLL)

17.4.1 The escape route or low location lighting (LLL) required by the Naval Authority, where satisfied by electric illumination, is to comply with the requirements of this sub-Section.

17.4.2 The LLL system is to be provided with an emergency source of electrical power as required by 3.2 and also connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.14.

17.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 10.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 11.3.7.

17.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ *Section 18* Ship safety systems

18.1 Watertight doors

18.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.6 in the event of failure of either the main or emergency source of electrical power.

18.1.2 Where the sources for opening and closing the watertight doors have electric motors, unless an independent temporary source of stored energy is provided, the electric motors are to be capable of being automatically supplied from the transitional source of emergency electrical power.

18.1.3 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

18.1.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

18.1.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

18.1.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
(b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 standard.

18.1.7 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimised.

18.1.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in crew areas and areas where the noise level exceeds 85 dB(A).

18.1.9 Sliding watertight doors are to be capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the respective control positions showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure.

18.1.10 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure; and
(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

18.1.11 The 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

18.1.12 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

18.1.13 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

18.2 Bow, stern and shell doors, loading doors and other closing appliances

18.2.1 Where it is required by Volume 1, Part 4, Chapter 3 that indicators be provided for bow, stern and shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the ships structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

18.2.2 Where such doors and appliances are to be operated at sea, the requirements of 18.1 are to be complied with as far as is practicable.

18.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

■ *Section 19* Lightning conductors

19.1 General

19.1.1 Lightning conductors complying with IEC 60092-401 are to be fitted to each mast of all wood, composite and steel ships having wooden masts or topmasts. They need not be fitted to steel ships having steel masts.

■ *Section 20* Testing and trials

20.1 Testing

20.1.1 Tests in accordance with 20.1.2 to 20.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

20.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of opposite polarity or phase.
For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 1.20.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for 1 minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 1.20.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \le 60$	500
$60 < U_n \le 1000$	$2 \times U_n + 1000$
$1000 < U_n \le 2500$	6500
$2500 < U_n \le 3500$	10000
$3500 < U_n \le 7200$	20000
$7200 < U_n \le 12000$	28000
$12000 < U_n \le 15000$	38000

20.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

20.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:
(a) all current carrying parts connected together and earth;
(b) all current carrying parts of different polarity or phase.
The minimum values of test voltage and insulation resistance are given in Table 1.20.2.

20.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

Table 1.20.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

20.2 Trials

20.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 20.2.2 to 20.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be to the Surveyor's satisfaction. A report having the results of measurements taken during the trials is to be submitted for record purposes.

20.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:
(a) all current carrying parts connected together and earth and, so far as is reasonably practicable;
(b) all current carrying parts of different polarity or phase;
The minimum values of test voltage and insulation resistance are given in Table 1.20.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

20.2.3 Tests are to be made to verify the effectiveness of:
(a) earth continuity conductor;
(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.11.2;
(c) bonding for the control of static electricity.

20.2.4 It is to be demonstrated that the Rules have been complied with in respect of:
(a) satisfactory performance of each generator throughout a run at full rated load;
(b) temperature of joint, connections, circuit-breakers and fuses;
(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;
(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;
(e) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;
(f) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory;
(g) propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed, is to be demonstrated at the sea trial.

20.2.5 Unless it has been satisfactorily shown by the design verification and validation process required by 1.8.4, that the power supply quality complies with the requirements of the defined standard, then compliance is to be demonstrated by measurements taken at the switchboards/section-boards used to supply sensitive military loads (*see* 1.8.1).

20.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew emergency and ship safety systems.

20.2.7 On completion of the general emergency alarm system and the crew and embarked personnel address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

20.3 High voltage cables

20.3.1 Before a new high voltage cable installation, or an addition to an existing installation, is put into service a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after the insulation resistance test required by 20.2.2 and may use either an a.c. voltage at power frequency or a d.c. voltage.

20.3.2 When an a.c. voltage withstand test is carried out, the voltage is to be not less than the normal operating voltage of the cable and it is to be maintained for a minimum of 24 hours.

20.3.3 When a d.c. voltage withstand test is carried out, the voltage is to be not less than:
(a) 1,6 (2,5U_o + 2 kV) for cables of rated voltages (U_o) up to and including 3,6 kV; or
(b) 4,2U_o for higher rated voltages where U_o is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed.
The test voltage is to be maintained for a minimum of 15 minutes. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test in accordance with 20.2.2 is then to be repeated.

20.4 Hazardous areas

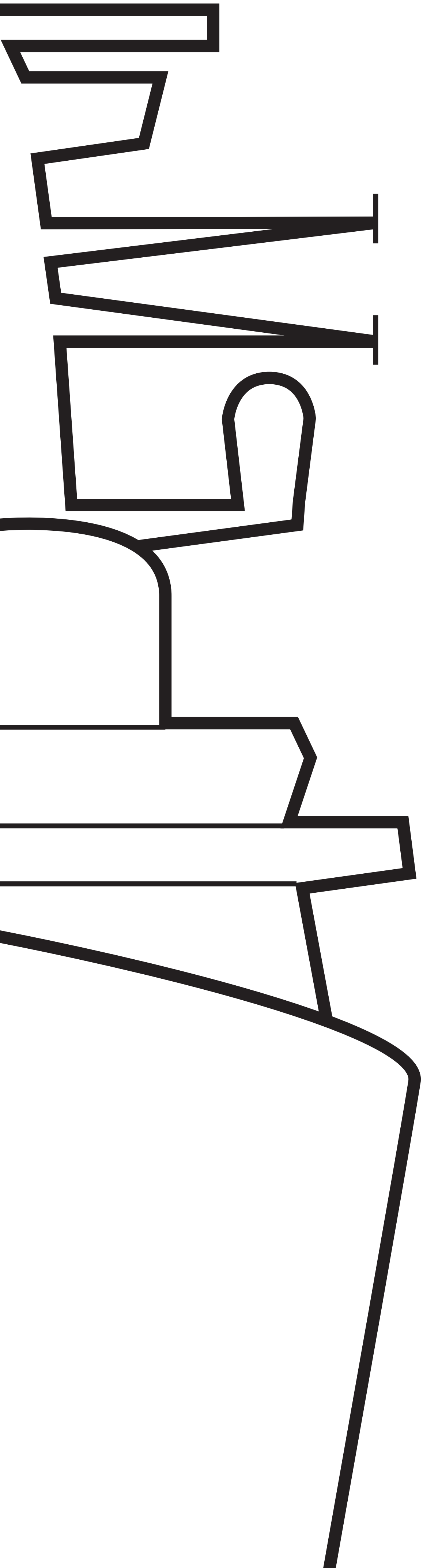
20.4.1 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules, has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired.

20.4.2 Alarms and interlocks associated with pressurised equipment and the ventilation of spaces located in hazardous areas are to be tested for correct operation.

■ *Section 21* **Spare gear**

21.1 General

21.1.1 It is recommended that adequate spares, together with the tools necessary for maintenance, or repair, be carried. The spares are to be determined by the Owner according to the design and intended service. The maintenance of the spares is the responsibility of the Owner.



Rules and Regulations for the Classification of Naval Ships

Volume 2 *Part 11*

Support systems

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Lloyd's Register

Chapter Contents

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■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for made and fresh water systems installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, piping and control systems necessary for the production and distribution of made and fresh water systems for domestic and other systems requiring defined quality and quantity capabilities.

1.1.3 The Naval Authority may impose requirements additional to those in this Chapter.

1.2 Scope

1.2.1 Made and fresh water systems included in this Chapter are for:

(a) Use of crew and embarked personnel for domestic services and food preparation.
(b) Use in cooling water systems.
(c) Use in chilled water systems, *see* Pt 7, Ch 5.
(d) Use in boiler feed systems.
(e) Use for bridge window washing arrangements.

1.2.2 Where the Owner/Operator requires the capability of the made and fresh water systems for purposes other than those listed in 1.2.1 (e.g. engine and aircraft washing), the Owner/Operator is responsible for defining the requirements for quality and quantity capabilities.

1.3 Plans and information

1.3.1 In addition to the information required by Pt 7, Ch 1,2.1.1, three copies of the plans and information stated in 1.3.2 to 1.3.8 are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **Design statement**. A design statement of the made and fresh water system that details system capability and functionality under defined operating and emergency conditions within the normal concept of operation role of the ship. The design statement is to be agreed between Designers and Owners/Operators. *See* 3.1.1, 3.2.2, 3.2.3, 3.3.2, 3.4.2, 3.4.6 and 5.3.1 for specific references to design statement.

1.3.3 **Systems**. Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems covered by this Chapter. The major component parts, pipe sizes, system flow rates and pressures together with the capacities of pumps and plants for making water are to be included in the plans.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the arrangements installed for making, storage and distribution of water and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in Section 3 and as required by Section 5.

1.3.6 **Operating manuals**. Operating manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars and a description of the systems for the production, storage and distribution of made and fresh water. The particulars are to include system arrangement plans showing each mode of operation of each system.
(b) Operating arrangements for each mode of operation for the equipment and systems installed.
(c) Cleaning arrangements and any precautions required for the use, storage and disposal of any recommended chemicals used for cleaning systems and equipment.
(d) Coating and maintenance instructions for water storage tanks.
(e) Cleaning instructions for filters, calorifiers and other equipment where bacteria may accumulate in fresh water systems for use of crew and embarked personnel and for food preparation.
(f) Maintenance instructions and fault finding procedures for the equipment and systems.

1.3.7 **Certificates**. Coating specification with certificate of testing for toxicity and tainting testing by an independent test laboratory.

1.3.8 **Specification**. Specification of metallic and non-metallic materials in contact with made and fresh water.

■ *Section 2*
Construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to any restrictions in Pt 7, Ch 1.

2.1.2 Where applicable, the materials are to comply with the requirements of Pt 7, Ch 1.

2.1.3 The selection of materials in piping systems is to recognise the following details:
(a) Fluid properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey, cleaning and maintenance requirements.

See Vol 2, Pt 7, Ch 1,17 for guidance notes on metal pipes for water services.

2.1.4 Materials for use in fresh water systems for use of crew and embarked personnel and for food preparation are to be of types that do not provide a habitat for bacteria which can occur with natural rubber, various plastics and fibre accessories, and do not leach out toxic constituents.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with Pt 7, Ch 1.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment – Selection and installation

2.3.1 Pressurised tanks are to be in accordance with a recognized and appropriate code and satisfy the Naval Authority's revalidation system for such items where applicable.

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of Pt 7, Ch 1, Sections 12 to 15, (*see also* 2.1 regarding selection of materials). The configuration of piping systems is to be arranged to minimise erosion and corrosion of pipe and equipment materials. Equipment used in made and fresh water systems and piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the Lists of LR Type Approved Products published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.3.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.4 Valves – Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting disks so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.5 Cathodic protection

2.5.1 Sacrificial anode cathodic protection is not permitted in made and fresh water storage tanks.

2.6 Coating of storage tanks and piping internal surfaces

2.6.1 Storage tanks, piping and valves constructed from carbon and low alloy steels and cast irons are to be lined internally with a corrosion control coating suitable for the containment and transfer of made and fresh water.

2.6.2 Corrosion control coatings are to be tested and certified as complying with standards specified by the Designer and agreed by the Naval Authority.

2.7 Plastics piping and flexible hoses

2.7.1 Subject to compliance with Pt 7, Ch 1,11 and Ch 1,13, and the relevant sections of Pt 7, Ch 2, plastics piping which is internally uncoated may be used in piping systems for made and fresh water.

2.7.2 Any internally uncoated plastics piping or flexible hose in contact with made or fresh water is to be suitable for the containment and transfer of made and fresh water.

2.7.3 Uncoated plastics piping and flexible hoses are to be tested and certified as complying with current standards for use in made and fresh water systems.

2.7.4 Plastics piping is to be selected in consultation with the manufacturers with regard to suitability with the proposed pipe system cleaning practice.

■ *Section 3* System arrangements

3.1 Water storage facilities

3.1.1 Sufficient potable water storage is to be provided to cater for the needs of the full ship's complement and embarked personnel recognising the operating role of the ship that is to be declared in the design statement required by 1.3.2. For example, a ship may be expected to spend some time in littoral waters where production of fresh water using installed plant may not be possible due to plant limitations or statutory regulations. The combination of storage, water production rate and usage is to be carefully considered in the vessel design, taking into account both average and peak loadings, the latter of which may be typically three times the normal usage rate.

3.1.2 At least two storage tanks are to be fitted, each with separate means of supplying the fresh water distribution main. The tanks are to be spacially separated and in NS1 and NS2 type ships at least one of the tanks is to be sited other than in the double bottom space. The tanks are to sited and be of such dimensions that they are readily accessible to facilitate inspection, cleaning and coating.

3.1.3 The internal structure of fresh water tanks is to be designed to ensure efficient drainage to the suction point. Fresh water tanks are not to have a common boundary with another tank that can contain oil or any other liquid except fresh water ballast. Access arrangements to storage tanks are to be arranged and sited clear of sources of possible contamination.

3.1.4 Pipes other than piping containing fresh water of the same quality as the tank contents are not to pass through or be located within a fresh water tank. Pipes carrying fresh water are not to pass through tanks other than fresh water tanks.

3.1.5 The storage facilities for made water intended for boiler feed services are to be independent of potable water systems for crew and embarked personnel. The storage and piping arrangements are to comply with Pt 7, Ch 3,6.

3.1.6 Water storage tanks are to be provided with means of indicating the water level. The means of routine level inspection is to be by means other than by the use of sounding rods.

3.1.7 Air, filling and sounding arrangements for fresh water storage tanks are to located and arranged to prevent an ingress of contamination.

3.1.8 Where required by the Naval Authority, separate storage tank(s) in addition to the two storage tanks required by 3.1.2 is/are to be provided. The tank(s) is/are to be provided with means for treatment of water in the tank for decontamination or other purposes that may be specified by the Naval Authority.

3.2 Made water production facilities

3.2.1 Made water production facilities fitted are to be capable of producing water to World Health Organisation *Guidelines for Drinking Water Quality, Volume 1 Recommendations Second Edition 1994* as a minimum requirement. A more stringent quality of water production may be necessary in the case of water for use in, for example, boiler feed systems. In these cases, an alternative means of water production is to be provided or a further stage of desalination included in the production arrangements. Where the required standards for made water are other than the World Health Organisation Standards, these are to be stated by the Naval Authority.

3.2.2 The total capacity of the fresh water generation plant will depend upon a number of parameters including complement, ship operating profile and other equipment supplied but typically will be of the order of 135 litres/man/day plus 450 litres/aircraft/day. The capacity of the plant and tank storage is to be agreed between the Designer/Owner/ Operator and declared in the design statement required by 1.3.2.

3.2.3 Two or more plants for making water are to be provided of sufficient combined capacity to produce sufficient water under defined levels of requirements stated in the design statement required by 1.3.2. Provision of single plant will be considered in conjunction with the operational requirements of the Naval Authority and any assigned service restriction.

3.2.4 The design of plants for making water is to be such that permits cleaning, maintenance and repair of any plant whilst the other is in service.

3.2.5 Adequate cleaning arrangements are to be fitted to water generating plants. A suitable safe area is to be designated for system cleaning agents.

3.2.6 In the case of distilling type plants, adequate safeguards are to be incorporated to prevent excess steam pressure. Steam piping arrangements are to comply with Pt 7, Ch 3,5.

3.2.7 Where there are low-pressure evaporators using diesel engine jacket water as the heating medium, any corrosion inhibitors in the jacket water are specifically approved for that application.

3.2.8 Means are to be provided to automatically enable produced water that falls below specification to be prevented from being discharged into the supply for distribution into the fresh and made water storage and user systems. The arrangements are to minimize the risk of contamination of made water storage facilities if the made water quality from the plant falls below specification.

3.3 Piping system design

3.3.1 Piping system arrangements are to be such that the supply of made and fresh water can be made to essential systems such as chilled water, machinery fresh water cooling and boiler feed water in the event of a single failure or damage of a system or item of equipment. As far as possible, permanent connections to these systems are to be avoided to prevent contamination of the fresh water by additives such as corrosion inhibitors that may be present in the systems. Where it is essential to fit permanent connections, means are to be provided to isolate the systems from the fresh water supplies to ensure that cross contamination cannot take place when the systems are operating normally.

3.3.2 The design of piping systems is to recognise operational and manning philosophy for the vessel and is to be declared in the design statement required by 1.3.2.

3.3.3 Where a piping system has failed or been damaged, any resulting hazards are to be capable of being minimised.

3.3.4 All equipment fitted in piping systems is to be readily accessible to facilitate maintenance and survey. For this purpose, valves or cocks are to be interposed between items of equipment and the inlet and outlet pipes in order that any item of equipment may be shut off for opening up and overhauling.

3.3.5 Any filter elements fitted in equipment or piping systems are to be capable of being cleaned and/or changed.

3.3.6 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted that will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time.

3.3.7 Seawater valves and fittings are to comply with Pt 7, Ch 2,2.5.

3.3.8 Not less than two sea inlets are to be provided for pumps supplying seawater to the fresh water generating plants. The sea inlets are to be independent of other sea inlets and are to be located forward and clear of any bilge or sanitary discharges.

3.3.9 Where a high pressure sea water system is installed (*see* Pt 7, Ch 5), provision is to be made for emergency supply to the made water plant.

3.3.10 Provision is to be made for all seawater to pass through suitable filters before being introduced to the made water plant. The filters are to be in accordance with the equipment manufacturer's recommendations.

3.3.11 Piping system arrangements and associated equipment are to be capable of operating satisfactorily under the conditions shown in Table 2.4.1 in Pt 1, Ch 2.

3.3.12 The system is to be capable of being cleaned with arrangements for safely flushing out any cleaning chemical agents after use and for storing or disposing of them safely.

3.4 Piping system distribution

3.4.1 Two or more water pumps are to be provided of sufficient capacity to supply the water distribution system with any one pump out of action.

3.4.2 The water distribution system is to be capable of providing a steady flow of water at any point in the system in accordance with the design statement required by 1.3.2. Where a pneumatically pressurised tank arrangement is used, the tank is to be provided with water level indication and a means of indicating the pressure. The compressed air connection to the pressurised tank is to incorporate a non-return valve arrangement at the tank to prevent the possibility of water entering the compressed air system and it is recommended that the connection be made via a portable hose connection.

3.4.3 Each user or group of users of fresh water are to be provided with means of isolation such that the distribution system can continue to function when a user or group of users has been isolated.

3.4.4 Air vent and drain points are to be provided throughout the system at all high and low points.

3.4.5 Provision is to be made for filling the water storage system(s) from the made water production facilities. Shore connection located above the waterline and an associated dry main are to be provided to permit the filling of the storage system.

3.4.6 Provision is to be made to connect an alternative source of water supply to defined services in emergency/action damage conditions. For example, where the fresh water main is unavailable, stand-by arrangements are to be provided for suitable water supplies to medical spaces, galleys, bridge window sprays, cleansing stations (NBC Protection fitted vessels) and weapon cooling. The supply arrangements to defined services in emergency/action damage conditions are to be included in the design statement required by 1.3.2 and agreed by the Owner/Operator.

3.4.7 There are to be no permanent connections between fresh water and sea water systems. Where emergency connections have been designed for the supply of fresh water to fresh and seawater cooled equipment, the fresh water is to be supplied by means of a portable hose with screw down non-return valve isolation arrangements at the connection to the equipment.

3.4.8 The temperature of domestic hot water systems is to be maintained above 63°C except in cases of peak demand when a fall to no less than 60° is acceptable. The distribution system is to be provided with a means of continuous circulation to resist bacteriological contamination of the system.

3.4.9 Calorifiers are to be provided with drainage arrangements and adequate access to enable cleaning.

3.4.10 Provision is to be made for all water supplies intended for domestic services and food preparation to be sterilised by chlorination that maintains residual free chlorine content of 0,2 ppm or by an equivalent sterilisation method. Means are also to be provided to chlorinate all fresh water taken from shore, water barge or supply ship on loading to a sufficient concentration to ensure a residual free chlorine content of 0,2 ppm.

3.4.11 The water supply arrangements intended for crew and embarked personnel for drinking, washing or food preparation is to be independent of other services wherever possible. Where there are no alternative supply arrangements to other services requiring fresh water (e.g. machinery cooling water, purifiers or a fresh water WC flushing system), a clear air break is to be provided in the fresh water supply pipe to such a system or tank. If it is impracticable to provide a clear air break, the supply pipe to each system is to be provided with an efficient non-return valve and a vacuum breaker or back-flow preventer.

■ *Section 4* Control and monitoring and electrical power arrangements

4.1 General

4.1.1 The control engineering arrangements are comply with Pt 9, Ch 1 as applicable.

4.1.2 Equipment used in made and fresh water systems is to be provided with local control and monitoring arrangements.

4.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

4.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at each control station.

4.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at the control station.

4.1.6 Made water plant instrumentation is to include, as a minimum, salinity indication and high salinity alarm of the made water at the plant and at each control station.

4.1.7 Arrangements are to be made to automatically divert any made water that is above the specified salinity limit from distribution into the made water storage system.

4.1.8 Made water systems using reverse osmosis plant are to be provided with automatic means of chlorinating the made water downstream of the plant.

4.1.9 Calorifiers are to be provided with a means of indicating and controlling the outlet temperature of fresh water to distribution systems. Low and high temperature alarms are to be provided in the hot water distribution system at each control station.

4.1.10 The electrical engineering arrangements are to comply with Pt 10, Ch 1.

■ *Section 5* Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*See* Pt 8, Ch 2,10 and Pt 7, Ch 1,16).

5.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

5.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

5.1.4 Testing is to cover the following items.

(a) Verification of control, alarm, safety systems.

(b) Tests simulating failure of made water production equipment and pumps to verify correct functioning of alarms and systems in service.

(c) Verification of accuracy, calibration and functioning of temperature control for hot water heating, monitoring and recording instrumentation for produced water systems where fitted.

5.2 Type testing

5.2.1 Evidence that the required performance of made water and pumping equipment is capable of being maintained under ambient and inclination operating conditions defined in Pt 1, Ch 2,4.4 and 4.5 is to be provided by the manufacturer.

5.3 Trials

5.3.1 Trials are to be carried out to demonstrate that the capability of the production, storage and distribution systems for made and fresh water systems meet the design statement. The trials are as far practicable to be representative of the actual conditions to be encountered in service.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for heating, ventilation and cooling arrangements (HVAC) systems installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, and control systems necessary for effective heating, ventilation and cooling arrangements on board a naval ship.

1.1.3 The Naval Authority may impose requirements additional to those in this Chapter.

1.2 Scope

1.2.1 HVAC systems included in this Chapter cover the following as applicable.

(a) Crew and embarked personnel spaces.
(b) Magazines and stores and spaces containing flammable liquids and gases.
(c) Storerooms, workshops, sewage handling spaces.
(d) Galleys.
(e) Medical spaces.
(f) Welldecks.

1.2.2 This Chapter also includes requirements for smoke clearance.

1.2.3 Machinery space ventilation systems are to comply with Pt 1, Ch 2,5.6.

1.2.4 Pump room ventilation systems are to comply with Pt 7, Ch 5,3 as applicable.

1.2.5 Vehicle, helicopter and aircraft space ventilation arrangements are to comply with Pt 10, Ch 1,13.9 as applicable.

1.2.6 NBC Protection guidance for ventilation is contained in Pt 1, Ch 2,4.11.

1.2.7 The requirements of Pt 7, Ch 5 are also applicable where a chilled water system is used for cooling purposes.

1.2.8 Battery room ventilation arrangements are to comply with Pt 10, Ch 1,11.5.

1.3 Plans and information

1.3.1 Three copies of the plans and information stated in 1.3.2 to 1.3.6 are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **Design statement**. A design statement of the HVAC systems that details system capability and functionality under defined operating and emergency conditions within the normal concept of operation role of the ship. The design statement for HVAC arrangements for the ship is to be agreed between the Designer and Owner/Operator. *See* 2.4.1, 2.5.1, 2.6.1, 3.1.2(d), 3.1.4, 3.3.1 3.6.1 and 5.3.1 for specific references to design statement.

1.3.3 **Systems**. Plans in diagrammatic form showing air intake/exhaust/distribution arrangements, control systems and safeguards and electrical systems covered by this Chapter. Plans are to show trunk/pipe sizes, air/water flows and terminal locations. The capacities of fans, pumps and heating/cooling/filtration plants are to be included. Capacity tables for different operating conditions for the refrigeration compressors are also to be included.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the equipment and arrangements installed for isolation, heating/cooling/filtration and distribution of ventilation air and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in Section 3.

1.3.6 **Operating manuals**. Operating manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems (including fire isolation aspects).
(c) Maintenance instructions for the installed arrangements.

■ *Section 2*
Construction and installation

2.1 Materials

2.1.1 The selection of materials in piping systems for heating, cooling and filtration systems is to recognise the following details:
(a) Fluids, pressures and temperatures.
(b) Location.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) Flammability and toxicity.

2.1.2 Ventilation trunk materials and characteristics are to be selected to suit the application. For example, watertight or gastight trunking may be required in certain areas of the vessel in order to meet the design requirements. Steel trunking is to be used in areas of high fire risk.

2.1.3 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to the restrictions in Pt 7, Ch 1.

2.1.4 Where applicable, the materials are to comply with the requirements of Pt 7, Ch 1.

2.2 Equipment – Selection and installation

2.2.1 Pressure vessels in heat exchange systems are to be in accordance with a recognised code and satisfy the Naval Authority's revalidation system for such items where applicable.

2.2.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of Pt 7, Ch 1,12 to 15.

2.2.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.2.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.2.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.2.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.2.7 Low temperature pipes in refrigeration systems are to be provided with efficient insulation. Chilled water and hot water pipes are also to be provided with insulation for system efficiency.

2.2.8 Means are to be provided, where necessary, to enable lengths of ventilation trunking to be cleaned internally.

2.3 Valves and isolation flaps – Installation and control

2.3.1 Valves and isolation flap arrangements are to be fitted in places where they are at all times readily accessible.

2.3.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.3.3 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.4 Refrigerant systems for cooling

2.4.1 Where chilled water systems complying with Pt 7, Ch 5 are not used for cooling ventilation air, independent refrigeration plants are to be provided and designed to be capable of extracting a defined heat load duty when operating at the conditions stated in the design statement required by 1.3.2. Independent refrigeration plants are to comply with the requirements of this Chapter.

2.4.2 The compartments containing the refrigeration plants are to be provided with refrigerant gas detectors with audible and visual alarms.

2.4.3 The design of refrigeration systems is to be such that permits maintenance and repair without unavoidable loss of refrigerant to atmosphere. To minimise refrigerant release to the atmosphere, refrigerant recovery units are to be provided for evacuation of a system prior to maintenance.

2.4.4 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances that would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved.

2.4.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

2.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valves is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

2.4.7 Omission of one of the specified relief devices and changeover device, as required by 2.4.6, will be accepted where:

(a) Vessels are of less than 300 litres internal gross volume.
or
(b) Vessels discharge into the low pressure side by means of a relief valve.

2.4.8 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

2.4.9 Seawater systems for refrigeration condensers are to be capable of being supplied from not less than two independent sources. If required by the Naval Authority, these sources are to be located in separate compartments and zones such that the loss of one zone or compartment will not result in the loss of all seawater supply sources.

2.4.10 The capacity of each source of seawater required by 2.4.9 is to be sufficient for the conditions stated in the design statement with any one source out of action.

2.5 Heating plant

2.5.1 Independent means of heating the air supplies to ventilation systems for crew and embarked personnel are to be designed to be capable of transferring a defined heat load duty when operating at the conditions stated in the design statement required by 1.3.2.

2.6 Filtration units for air intakes

2.6.1 Air inlets and outlets to all ventilation systems are to be provided with suitable protection screens. Filtration units are to be provided at all inlets to air supplies to ventilation systems for crew and embarked personnel in accordance with the conditions stated in the design statement.

2.6.2 Air filtration units are to be provided to control the ingestion of water, particulate and corrosive marine salts and are to be capable of being cleaned in accordance with the manufacturer's recommendations.

2.6.3 Filtration units for NBC Protection are to be in accordance with the guidance in Pt 1, Ch 2,4.11 as applicable.

■ *Section 3* System arrangements

3.1 General

3.1.1 The design of air-conditioning and ventilation systems is to reflect the total ship design including any NBC Protection requirements, fire/damage zoning or other particular features stipulated in the Naval Authority specification for the vessel.

3.1.2 The design and capability of supply and exhaust systems for ventilation purposes are to address the following requirements as applicable:

(a) Noxious odours, toxic and dangerous fumes or other contaminants are to be extracted, taking into account any requirements of the Naval Authority.
(b) Acceptable levels of fresh air are to be provided for personnel efficiency, combustion or other oxidation processes. The arrangements are to ensure that maximum CO_2 levels are not exceeded in all spaces where crew and embarked personnel are likely to be. A maximum CO_2 level of 1200 ppm is to be adopted unless the Naval Authority specifies a greater or lesser level. A high level alarm is to be provided where 100 per cent recirculation is adopted for any ship operational requirement. A minimum fresh air flow of 5 litres/s/man is to be capable of being supplied to all spaces intended for crew and embarked personnel.
(c) In a fire situation within an autonomous zone, smoke migration is to be restricted to prevent ingress into compartments essential for the operational capability of the ship in a fire situation.
(d) Acceptable internal ambient conditions are to be maintained for personnel comfort in manned compartments and in other compartments where required for equipment cooling. The arrangements for maintaining acceptable ambient conditions are to take account of the range of climatic conditions that the ship is required to operate within and are to be included in the design statement required by 1.3.2.
(e) Systems are to be arranged so that as far as is practicable they serve like compartments from the same sub-systems.
(f) If the vessel is divided into autonomous zones, the systems are to be designed so that they do not cross over from one zone boundary to another.
(g) In the case of vessels designed for NBC Protection, the system is to be designed to maintain the vessel at an overpressure relative to the outside ambient pressure. The system is also to provide a breathable atmosphere, minimising CO_2 levels with the maximum ship's complement. Odour filtration is to be provided for all those areas that are likely to produce foul smells and are subject to recirculation in closedown, e.g. bathrooms, toilets, galleys. *See* Pt 1, Ch 2,4.11 for NBC Protection guidance.
(h) The systems are to be designed to maintain the vessel's watertight integrity and, for ships with NBC Protection arrangements, gastight integrity.
(j) Systems are to be designed to enable inspection, cleaning and maintenance in accordance with the designer's and equipment manufacturer's recommendations.

3.1.3 Exhausts from clean workshops may be returned to the ship's recirculation system via suitable filter arrangements. However, the air conditioning system is not to be used for dust extraction from woodworking machinery, etc. Independent extraction systems are to be used for this purpose. Similarly, fumes from welding bays, etc., are to be exhausted to atmosphere.

3.1.4 Exhausts from sewage treatment spaces are normally to be led to atmosphere. Where identified in the design statement, exhausts may be led to the ship's recirculation system but means of isolation to the recirculation system with alternative exhaust to atmosphere arrangements are to be provided to cater for abnormal plant conditions.

3.1.5 Exhausts from storerooms containing non-hazardous materials may be returned to the ship's recirculation system.

3.1.6 Exhaust arrangements from machinery spaces, pump room, aircraft and vehicle decks are to be led to atmosphere.

3.1.7 All openings in weatherdeck boundaries are to be fitted with grilles to avoid ingress of debris. Consideration is to be given to weatherdeck openings to prevent down-flooding.

3.1.8 Facilities are to be provided to ensure that weatherdeck openings remain clear of ice when the ship is operating in the coldest climate for which it is designed.

3.1.9 In compartments or spaces with low noise targets or in operational spaces, accommodation, working or office areas, the design of the distribution system is to be such as to minimise noise generation.

3.2 Magazines, stores and spaces containing flammable liquids and gasses/vapours

3.2.1 The design of ventilation arrangements to magazines is to minimise the risk of explosion. Where fitted, exhausts from magazines are to be led to atmosphere.

3.2.2 Systems serving compartments containing flammable stores (e.g. paint stores) or potentially explosive gases (including battery charging rooms, oxygen bottle stores and magazines) are to be fitted with flameproof gauzes and isolating valves in these branches. The systems serving such compartments are to be independent of those supplying other spaces. Fans supplying and extracting air to/from such compartments are to be spark resistant as a minimum. Exhausts are to be led to atmosphere away from other outlets, i.e. fuel tank vents.

3.2.3 Exhausts from compartments containing hazardous materials, including dangerous or noxious gases (e.g. refrigeration machinery), are to be led to atmosphere.

3.2.4 Electrical equipment (including any heating arrangements) for magazines, stores and spaces containing flammable gasses and vapours is to comply with Pt 10, Ch 1.

3.3 Galleys

3.3.1 The following arrangements are to be incorporated in ventilation systems within galleys:

(a) All trunking is to be of steel or stainless steel.
(b) Exhaust terminals above equipment such as fryers, grills, etc, are to be fitted with grease filters that can easily be removed and cleaned.
(c) Exhaust branches, fitted with grease filters, are to be protected by fire flaps within the galley. The flaps are to be sited in the exhaust trunking between the canopy and the exit from the galley, arranged to close in the direction of air flow and be readily operable from both within and outside the galley.
(d) CO_2 injection or other fire extinguishing means facilities are to be fitted.

Exhaust systems from galleys are normally to be led to atmosphere. In the case of ships fitted with NBC Protection and when identified in the design statement, the galley ventilation system may be designed to recirculate air and, to limit food smells, odour filtration is to be provided. If the exhaust is led to atmosphere in ships fitted with NBC Protection, the air loss is to be considered when assessing the NBC arrangements.

3.3.2 In addition to those fitted in galley systems, fire flaps are also to be fitted:

(a) In ventilation trunks that pass through designated fire barriers.
(b) In ventilation trunks that pass through watertight bulkheads where this penetration occurs within the lines of weathertight and watertight integrity as defined in Vol 1, Pt 3, Ch 2.

3.4 Medical spaces

3.4.1 Sick bay complexes are to be provided with a dedicated air treatment unit with trunked distribution, fresh air, recirculation and where necessary, exhaust systems.

3.4.2 The arrangements for ventilation of medical compartments are to be such that they are capable of maintaining a positive pressure in relation to the surrounding complex to prevent the ingress of any contaminated air. Similarly, any operating theatres are to have arrangements for providing a relative positive pressure to the adjacent medical spaces.

3.5 Welldecks

3.5.1 Welldeck spaces are to be designed with ventilation systems that provide a safe working environment for a defined period of time which in general should be not less than 8 hours.

3.5.2 Guidance for the design of ventilation systems for welldeck spaces can be found in IMO MSC/Circular 729 – *Design Guidelines and Operational Recommendations for Ventilation Systems in Ro-Ro Cargo Spaces*.

3.6 Smoke clearance

3.6.1 In addition to the requirements in 3.1 to 3.5, the Naval Authority may also require the installation of a smoke clearance system. The design of such a system is to be based on the declared operating philosophy identified in the design statement required by 1.3.2 which in general should recognise that smoke clearance is only undertaken when a fire has been extinguished since any attempt to clear smoke before a fire has been extinguished could introduce more air to the fire. Dedicated fixed smoke clearance trunking is to be of steel construction and both this and the fans are to be capable of operating at the temperatures of the exhaust gas from the extinguished fire but, in any case, not less than 250°C. Portable fans of suitable design may also be used with temperature resistant flexible trunking. Clearance of smoke is to be such that unaffected parts of the ship are not contaminated with smoke.

■ *Section 4*
Control and monitoring and electrical power arrangements

4.1 General

4.1.1 The control engineering arrangements are comply with Pt 9, Ch 1 as applicable.

4.1.2 The equipment used in HVAC systems is to be provided with local control and monitoring arrangements.

4.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

4.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at any control station.

4.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at each control station.

4.1.6 The power to all independently driven ventilation fans is to be capable of being stopped from position(s) outside the fire boundary which will always be readily accessible in the event of fire occurring in any space, as well as from the local control panel.

4.1.7 Electrical engineering arrangements are to comply with Pt 10, Ch 1.

4.1.8 Refrigeration compressors are to be provided with the following instrumentation and automatic shutdowns.
(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure which is to operate at a pressure in excess of normal operating pressure but not greater than 0,9 of the maximum working pressure.
(g) Automatic shutdown in the event of a low suction pressure.

4.1.9 For refrigeration compressors greater than 25 kW, the following instrumentation, additional to that required by 4.1.8, is to be provided:
(a) Indication of lubricating oil temperature.
(b) Indication of cooling water outlet temperature.
(c) Indication of suction and discharge temperatures.

4.1.10 Alarms are to be initiated in the event of the following fault conditions with refrigeration compressors:
(a) High discharge pressure.
(b) Low suction pressure.
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

4.1.11 Refrigeration plants are to be provided with the following alarms:
(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans.
(d) High and low chilled water delivery temperatures.

4.1.12 Ventilation air heating/cooling plants are to be provided with the following instrumentation and alarms as applicable:
(a) Indication of heating/cooling medium temperature.
(b) Indication of delivery air temperature.

4.1.13 Filter units for ventilation systems for crew and embarked personnel installations are to be provided with the following instrumentation and alarms:
(a) Indication of differential air pressure across the filter unit.
(b) High differential air pressure alarm.

■ *Section 5* Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*See* Pt 8, Ch 2,10 and Pt 7, Ch 1,16).

5.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

5.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

5.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety systems.

(b) Tests simulating failure of HVAC equipment to verify correct functioning of alarms and systems in service.

(c) Verification of accuracy, calibration and functioning of temperature control for HVAC systems.

5.2 Type testing

5.2.1 Evidence that the required performance of heating/cooling/filtration systems, pump and fan equipment is capable of being maintained under ambient and inclination operating conditions defined in Pt 1, Ch 2,4.4 and 4.5 is to be provided by the manufacturer.

5.3 Trials

5.3.1 Trials are to be carried out to demonstrate that the capability of the HVAC systems meets the design statement. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for waste matter systems and arrangements installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, and control systems necessary for effective functioning of waste matter systems on board a naval ship.

1.1.3 The Naval Authority may impose requirements additional to those in this Chapter.

1.1.4 Where required by the Naval Authority, all Regulations of MARPOL Annex IV are to be complied with.

1.2 Scope

1.2.1 Waste matter systems included in this Chapter cover the following:
(a) Sewage waste.
(b) Galley waste.
(c) Grey water.
(d) Black water.

1.2.2 Oily wastes from machinery and other spaces are within the scope of the **EP** and **POL** class notations, *see* Vol 3, Pt 2, Ch 2 and Vol 3, Pt 3, Ch 6.

1.2.3 **Sewage waste** means:
(a) Drainage and other wastes from any form of toilets, urinals and WC scuppers.
(b) Drainage from medical premises (dispensary, sick, etc.) via wash basins, wash tubs and scuppers located in such spaces.
(c) Other wastes waters when mixed with drainages defined in (a) and (b).

1.2.4 **Galley waste** means drainage from galleys that may be contaminated with food or other organic waste that may give rise to smell.

1.2.5 **Grey water** means drainage from baths, showers, sinks, and laundry systems.

1.2.6 **Black water** means drainage from sewage systems and chemical wastes that could constitute a recognized health and safety risk to persons on board.

1.3 Plans and information

1.3.1 Three copies of the plans and information stated in 1.3.2 to 1.3.7 are to be submitted to LR as applicable.

1.3.2 **Design statement**. A design statement of the waste systems that details system capability and functionality under defined operating and emergency conditions within the normal concept of operation role of the ship. The design statement for waste arrangements for the ship is to be agreed between the Designer and Owner/Operator.

1.3.3 **Systems**. Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems covered by this Chapter. The major component parts, pipe sizes, system flow rates and pressures together with capacities of pumps and plants and tanks are to be included. Any Standards or Design Guidance used for system design are to be stated.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the equipment and arrangements installed for handling, treatment, storage and disposal of waste and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in Section 3.

1.3.7 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The manuals are to include the following information:
(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems.
(c) Arrangements for the disposal of oily wastes from galleys.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to any restrictions in Pt 7, Ch 1,11.

2.1.2 Where applicable, the materials are to comply with the requirements of Pt 7, Ch 1.

2.1.3 The selection of materials in piping systems is to recognise the following details:
(a) Fluid properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey, cleaning and maintenance requirements.

See Vol 2, Pt 7, Ch 1,17 for guidance notes on metal pipes for water services.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with Pt 7, Ch 1.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment – Selection and installation

2.3.1 Pressurised tanks are to be in accordance with a recognised code and satisfy the Naval Authority's revalidation system for such items where applicable.

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of Pt 7, Ch 1,12 to 15, (*see also* 2.1 regarding selection of materials). The configuration of piping systems is to be arranged to minimise erosion and corrosion of pipe and equipment materials. Equipment used in waste piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the *Lists of LR Type Approved Products* published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.3.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.4 Valves – Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting disks so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.5 Coating of storage tanks and piping internal surfaces

2.6.1 The storage tanks and metallic piping and valves are to be lined internally with a corrosion control coating suitable for the containment and transfer of waste matter.

2.6.2 Corrosion control coatings are to be tested and certified as complying with standards specified by the Designer and agreed by the Naval Authority.

2.6 Plastics piping and flexible hoses

2.6.1 Subject to compliance with Pt 7, Ch 1,11 and 13, and the relevant Sections of Pt 7, Ch 2, plastics piping may be used in piping systems for waste matter.

2.6.2 Plastics piping is to be selected in consultation with the manufacturers with regard to suitability with the proposed pipe system cleaning practice.

■ *Section 3* System arrangements

3.1 Arrangements

3.1.1 The installation and arrangements of systems and equipment are to recognise the manufacturer's recommendations for the effective functioning of waste systems.

3.1.2 The arrangements for waste systems are to be such that they are capable of operating under all normal angles of heel and trim.

Normal angles of heel and trim are to be taken as:
(a) Ship on an even keel or has a list of not more than 5°.
(b) Ship on even trim or is trimmed not more than 5° for a ship up to 100 m in length. Where the length of the ship exceeds 100 m, the maximum trim may be taken as 500/*L* degrees where *L* = length of ship, in metres.
(c) The angles of heel and trim may occur simultaneously.

3.1.3 The piping system design for waste systems is to incorporate adequate fall and flow arrangements which exclude traps unless specifically required for system operation/cleaning. The determination of adequacy of full and flow is to be made with reference to a suitable and proven design standard.

3.1.4 The piping system arrangements are to be such that they are capable of being cleaned and unblocked.

3.1.5 The processing/storage capacity of waste systems is to take into account the operational profile of the ship and its complement. For example, the ship may spend a prolonged period of time in littoral waters where sewage discharge overboard, treated or untreated, is prohibited by the relevant national authority and, therefore, adequate holding capacity may need to be provided.

3.1.6 The waste systems are to be of sufficient capacity to handle peak flows in addition to an average flow. Typically, peak flows can be three times the average hourly flow but this should be confirmed during the design stage.

3.1.7 Variations in the complement of the ship are to be taken into account but the system must be capable of satisfactory operation with the minimum number of persons on board when the ship is at sea.

3.1.8 If only one sewage treatment plant is fitted then arrangements are to be provided to allow essential maintenance work to be undertaken on this plant whilst retaining full use of the remainder of the sewage and waste water system.

3.1.9 Drains from medical facilities are to be led to the black water side of the sewage treatment plants or holding tanks.

3.1.10 Vents from wastes systems are to terminate outside the vessel. However, where a vessel is required to be capable of operating within an NBC threat area then these vents are to be capable of being reconfigured to vent inside the citadel via charcoal filters.

3.1.11 Overboard discharges are to be arranged such that they are clear of accommodation ladders, areas where boats are loaded/unloaded, etc.

3.1.12 Arrangements are to be made for the disposal of oily wastes stemming from food preparation in galleys. Systems intended for the disposal of such oily wastes are to be separate from other waste systems. Suitable notices are to be provided advising that oily wastes are not to be disposed of.

■ *Section 4* Control and monitoring and electrical power arrangements

4.1 General

4.1.1 The control engineering arrangements are to comply with Pt 9, Ch 1 as applicable.

4.1.2 Equipment used in waste systems is to be provided with local control and monitoring arrangements.

4.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

4.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at each control station.

4.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at the control station.

4.1.6 The electrical engineering arrangements are to comply with Pt 10, Ch 1.

■ *Section 5* Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*See* Pt 8, Ch 2,10 and Pt 7, Ch 1,16).

5.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

5.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

5.1.4 Testing is to cover the following items:
(a) Verification of control, alarm, safety systems.
(b) Tests simulating failure of waste system equipment and pumps to verify correct functioning of alarms and systems in service.

5.2 Type testing

5.2.1 Evidence that the required performance of drainage and pumping equipment is capable of being maintained under ambient and inclination operating conditions defined in Pt 1, Ch 2,4.4 and 4.5 is to be provided by the manufacturer.

5.3 Trials

5.3.1 Trials are to be carried out to demonstrate that the capability of the waste systems meet the design statement. The trials are as far practicable to be representative of the actual conditions to be encountered in service.

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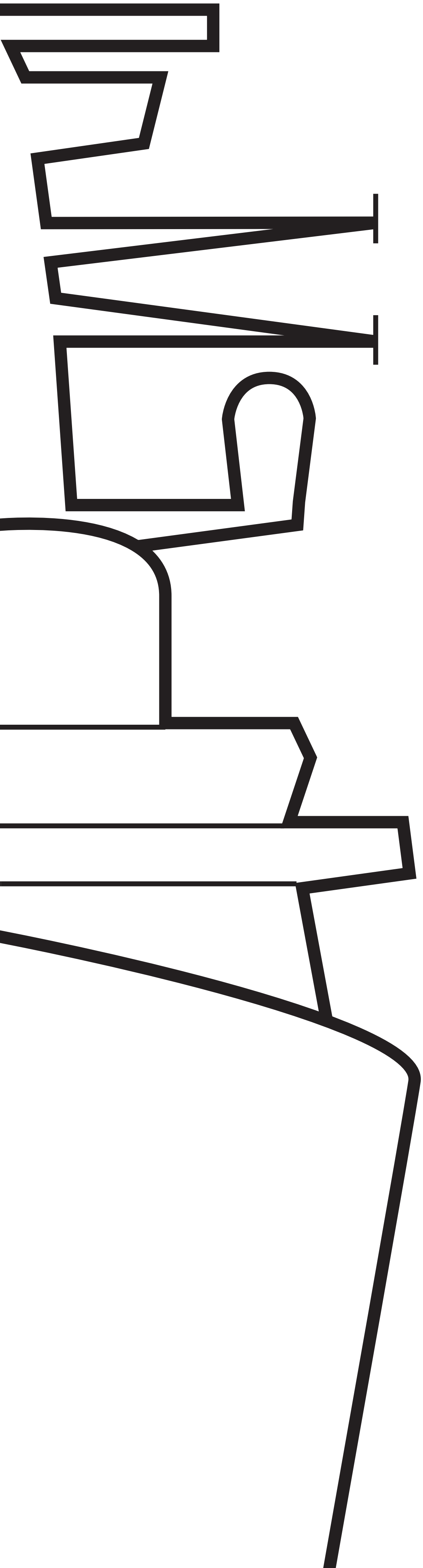


Rules and Regulations for the Classification of Naval Ships

Volume 3 *Parts 1–3*

Additional optional requirements

January 2005

Lloyd's Register

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set, individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 2, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda. A dot-dash line indicates changes necessitated by International Conventions, Code of Practice or IACS Unified Requirements.

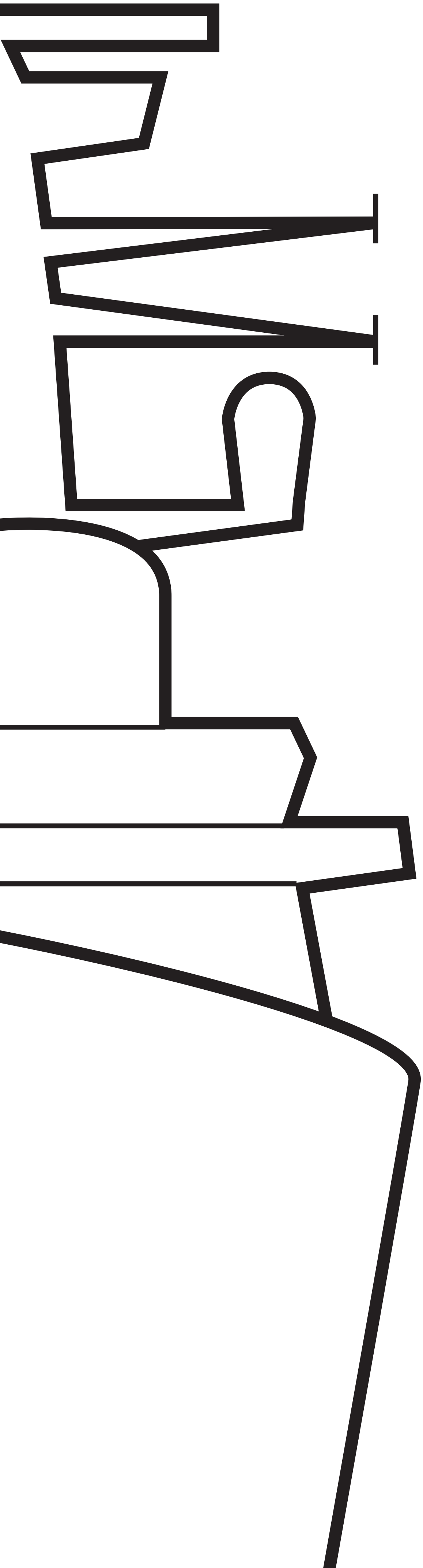
Rules programs

LR has developed windows based Rules Calculation Software which evaluates Rule Requirements for Special Service Crafts' structures. For details of this software please contact Lloyd's Register.

Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to Lloyd's Register's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2005



Rules and Regulations for the Classification of Naval Ships

Volume 3 *Part 1*

Additional sea-going features

January 2005

Lloyd's Register

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Volume 3, Part 1

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■ *Section 1* General requirements

1.1 Application

1.1.1 Where additional strengthening for the hull is fitted in accordance with the requirements of Section 2 and the machinery and engineering systems are in accordance with Section 3, an appropriate Ice Class notation will be assigned. *See* Vol 1, Pt 1, Ch 2,3.9.14.

1.1.2 The requirements for navigation in ice stated Sections 2 and 3 are intended for ships operating in first year ice irrespective of whether assistance from ice breakers is anticipated. The are not intended for ships designed to operate in multi-year ice conditions.

1.2 Plans and information

1.2.1 Plans and information showing compliance with the hull structure and machinery and engineering systems requirements are to be submitted for approval. The plans and information are to indicate compliance with Sections 2 and 3 and the information is to be incorporated in the plans and information submitted for approval in open water service conditions for the relevant Chapters in Volumes 1 and 2.

■ *Section 2* Hull strengthening requirements

2.1 Application

2.1.1 Where the notation 'Ice Class 1AS, 1A, 1B, or 1C as specified in Vol 1, Pt 1, Ch 2,3.9.14 is desired, the ship is to comply with the requirements of this Section, in addition to those for sea-going service, so far as they are applicable.

2.1.2 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in 2.2. The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

2.1.3 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the ice light waterline. Ballast tanks situated above the ice light waterline and adjacent to the shell, which are intended to be used in ice navigating conditions, are to be provided with heating pipes.

2.1.4 The requirements of this Section are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

2.1.5 The requirements of this Section assume that when approaching ice infested waters the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

2.1.6 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to Ice Class 1AS ships.

2.1.7 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

2.1.8 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, icebreakers may require local reinforcement in way of the stern fork.

2.2 Definitions (*see* Fig. 1.2.1)

2.2.1 The **Ice Deep Waterline** corresponds to the Deep Draught Waterline. Where specially requested and where permitted by the Naval Authority, an Ice Deep Waterline may be specified which differs from the foregoing, but corresponds to the deepest condition in which the ship is expected to navigate in ice. *See* Vol 1, Pt 3, Ch 1,5.3 for margins.

2.2.2 The **Ice Light Waterline** is that corresponding to the lightest condition in which the ship is expected to navigate in ice. However, it is recommended that the minimum draught at the fore end is not to be less than:

$$T_f = (1{,}5 + 0{,}1\sqrt[3]{\Delta})\,h \quad \text{m}$$

where

h = the nominal ice thickness, in metres, associated with the desired Ice Class, *See* Vol 1, Pt 1, Ch 2,3.9.14.

Δ = displacement as defined in 2.2.11.

2.2.3 The Ice Deep Waterline and the Ice Light Waterline are to be indicated on the plans.

2.2.4 The **Main Ice Belt Zone** extends vertically above and below the waterline defined in 2.2.1 and 2.2.2 by the distances shown in Table 1.2.1. For ships fitted with a bulbous bow, the vertical extent of the Main Belt Zone will be suitably increased.

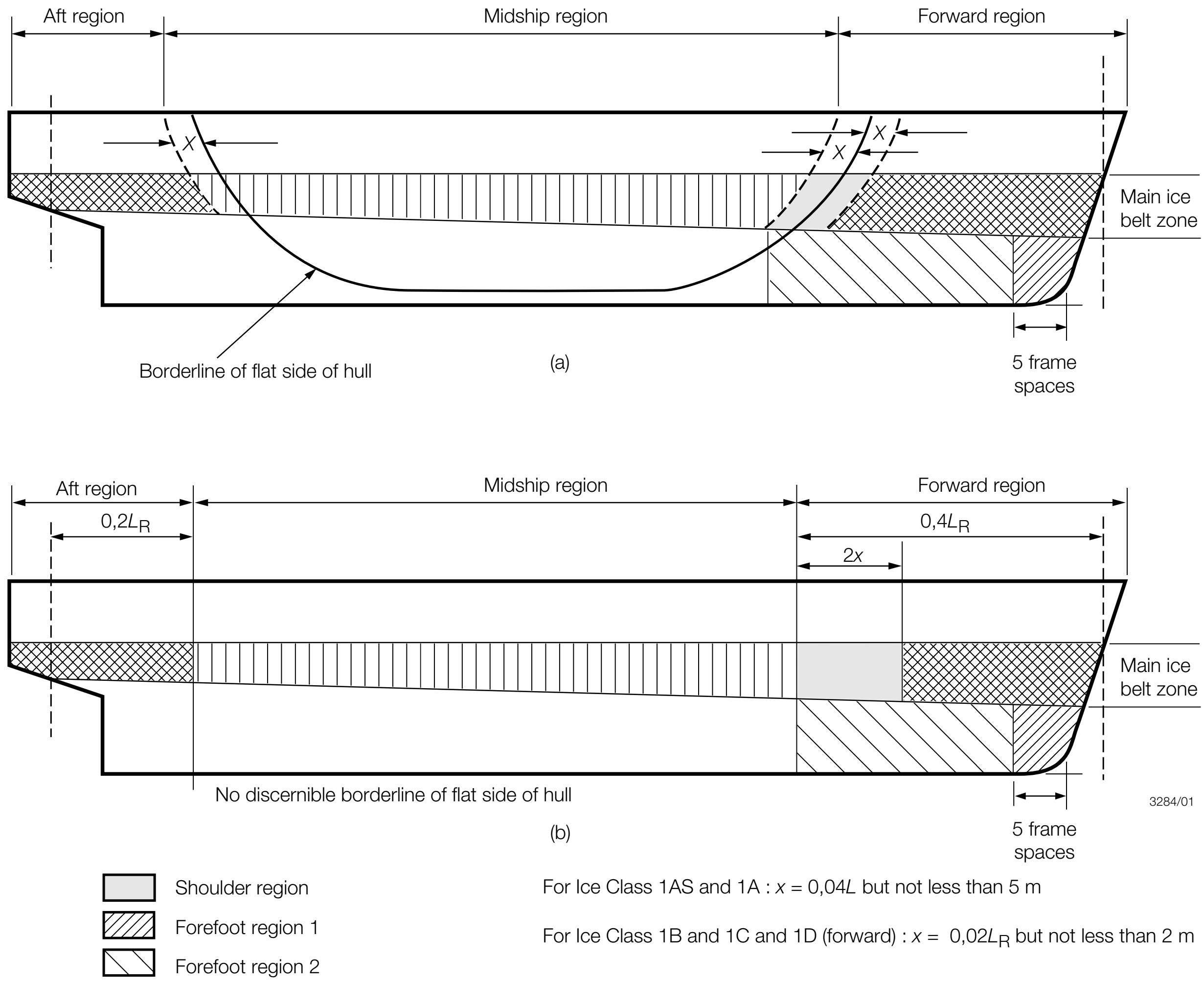


Fig. 1.2.1 Regions and zones (First year ice conditions)

Table 1.2.1 Vertical extent of main ice belt zone

Class	Above Ice Load Waterline (mm)	Below Ice Light Waterline (mm)
1AS	600	750
1A	500	600
1B	400	500
1C	400	500

2.2.5 The **Forward Region** extends from the stem to aft of the forward borderline of the flat side of the hull by a distance equal to the greater of $0{,}04L_R$ or 5 m for Ice Classes 1AS and 1A, or the greater of $0{,}02L_R$ or 2 m for Ice Classes 1B, and 1C. Where no clear forward borderline of the flat side of the hull is discernible, the aft boundary of the forward region is to be taken $0{,}4L_R$ aft of the forward perpendicular.

2.2.6 **Forefoot Region 1** is the area below the main ice belt zone extending from the stem, or the fore end of the bulb where a bulbous bow is fitted, to a position five frame spaces aft of the point of intersection between the level keel line and the raked stem.

2.2.7 **Forefoot Region 2** is the area below the main ice belt extending from the aft boundary of Forefoot Region 1 to the aft boundary of the forward region and encompasses both side and bottom shell plating.

2.2.8 The **Shoulder Region** is a part of the main ice belt zone in the forward region and extends from the aft boundary of the forward region to forward of the forward borderline of the flat side of the hull by a distance of $0{,}04L_R$ for Ice Classes 1AS and 1A or $0{,}02L_R$ for Ice Classes 1B and 1C. Where no clear forward borderline of the flat side of the hull is discernible, the forward boundary of the shoulder region is to be taken $0{,}32L_R$ aft of the forward perpendicular for Ice Classes 1AS and 1A or $0{,}36L_R$ aft of the forward perpendicular for Ice Classes 1B and 1C. The extent of the shoulder region forward of its aft boundary is not to be taken as less than 10 m for Ice Classes 1AS and 1A or 4 m for Ice Classes 1B and 1C.

2.2.9 The **Midship Region** extends from the aft boundary of the forward region to aft of the aft borderline of the flat side of the hull by a distance equal to the greater of $0{,}04L_R$ or 5 m for Ice Classes 1AS and 1A or the greater of $0{,}02L_R$ or 2 m for Ice Classes 1B and 1C. Where no clear aft borderline of the flat side of the hull is discernible, the aft boundary of the midship region is to be taken $0{,}2L_R$ forward of the aft perpendicular.

2.2.10 The **Aft Region** extends from the aft boundary of the midship region to the stern.

2.2.11 **Displacement** Δ is the displacement, in tonnes, at the Ice Deep Waterline when floating in water having a relative density of 1,0.

2.2.12 **Shaft power,** P_0, is the maximum propulsion shaft power, in kW, for which the machinery is to be classed.

2.3 Powering of ice strengthened ships

2.3.1 The total shaft power installed in ice strengthened ships is to be not less than P required by Section 3 for the desired Ice Class notation.

2.3.2 Ice strengthened ships which are to be considered to have an independent icebreaking capability are to be able to develop sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness equal to the nominal value specified in Vol 1, Pt 1, Ch 2,3.9.14 for the desired Ice Class and a snow cover of at least 0,3 m.

2.3.3 The requirements of 2.4 to 2.10 are formulated on the assumption that the shaft power necessary to provide an independent icebreaking capability as described in 2.3.2 can be determined by the equation:

$$P_1 = 0{,}736C_1\,C_2\,C_3\,C_4\,[240B\,h\,(1 + h + 0{,}035v^2) + 70S_c\sqrt{L}\,)]$$

where

B = breadth as defined in Vol 1, Pt 3, Ch 1,5

$C_1 = \dfrac{1{,}2B}{\sqrt{\Delta}}$, but is not to be taken as less than 1,0

C_2 = 0,9 if the ship is fitted with a controllable pitch propeller, otherwise 1,0

C_3 = 0,9 if the rake of the stem is 45° or less, otherwise 1,0. The product $C_2\,C_3$ is not to be taken as less than 0,85

C_4 = 1,1 if the ship is fitted with a bulbous bow, otherwise 1,0

h = ice thickness as defined in 2.2.2

S_c = depth of snow cover

v = ship speed, in knots, when breaking ice of thickness, h

2.3.4 The ice strengthening requirements of 2.4 to 2.10 include a power-displacement correction factor, γ, which is to be determined as follows:

(a) Forward region

$$\gamma = 0{,}653 + 3{,}217\sqrt{P_0\,\Delta} \times 10^{-5}$$

$$\text{or } \gamma = 0{,}876 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$$

or γ = 1,0 whichever is the least

where P_0 and Δ are as defined in 2.2.

For ships assigned Ice Classes 1AS and 1A, in which the installed shaft power P_0 exceeds the shaft power P_1 determined in accordance with 2.3.3 when the ship speed is taken as five knots, the ice thickness, h, as defined in Vol 1, Pt 1, Ch 2,3.9.14 and the snow cover S_c is taken as 0,3 m, γ for the forward region is to be multiplied by the following factor:

(i) for shell plating

$$1 + 0{,}1\,\frac{P_0 - P_1}{P_1}$$

(ii) for framing, stringers and web frames

$$1 + 0{,}05\,\frac{P_0 - P_1}{P_1}$$

but γ need not be taken greater than 1,1.

(b) Midship and aft regions

$$\gamma = 0{,}653 + 9{,}908\sqrt{P_0\,\Delta} \times 10^{-6}$$

or = 0,79, whichever is the lesser.

2.4 Shell plating

2.4.1 In way of the main ice belt zone, the thickness of the shell plating is not to be less than:

$$t = As\,\alpha_p\,\beta\,\gamma\sqrt{\frac{4{,}7}{\sigma_o}} + c \quad \text{mm}$$

where

c = corrosion-abrasion increment to be taken as 2 mm for first year Ice Classes, *see also* 2.4.3

s = distance to the adjacent main or intermediate frame, in mm

A = 0,40 in association with transverse framing
= 0,41 in association with longitudinal framing

α_p = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in Table 1.2.2

β = vertical distribution factor, to be taken as 1,0 for all first year Ice Classes

γ = power-displacement factor determined in accordance with 2.3.4

σ_o = specified minimum yield stress of the steel, in N/mm^2. For mild steel the value 235 N/mm^2 is to be used.

Table 1.2.2 Longitudinal distribution factor-shell plating

Ice Class	α_p		
	Forward	Midship	Aft
1AS	1,00	0,95	0,85
1A	0,98	0,86	0,73
1B	0,93	0,71	0,57
1C	0,86	0,53	0,38

2.4.2 Where operation in first year ice is an emergency feature as recognised by Vol 1, Pt 1, Ch 2,3.9.14 with a * annotated to the Ice Class notation, consideration will be given to the use of fully plastic design criteria for the shell plating.

2.4.3 If a recognised low friction surface coating is to be applied in way of the main ice belt and is to be maintained in good condition during service, the thickness determined in accordance with 2.4.1 may be reduced by 1 mm.

2.4.4 For Ice Classes 1AS and 1A, where the hull form includes a pronounced shoulder, the value of the corrosion-abrasion increment in the shoulder region will be specially considered.

2.4.5 For Ice Classes 1AS and 1A, the thickness of shell plating is to be as follows:

(a) In Forefoot Region 1 – not less than that determined in accordance with 2.4.1 for the main ice belt zone in the forward region.

(b) In Forefoot Region 2 – 2 mm greater than that required by Vol 1, Pt 6, Ch 3 or Vol 1, Part 7 for ships with TLA notation.

(c) For the forward $0{,}2L_R$ the region 2 m above the main ice belt zone in ships having an open water speed equal to and exceeding 17,5 knots (9 m/sec) – not less than that required in the ice belt in the Midship Region.

2.4.6 Changes in plating thicknesses in the longitudinal direction are to take place gradually. Side scuttles are not to be situated in the ice belt.

2.4.7 If the weather deck in any part of the ship is situated below the upper limit of the ice belt, as may be the case of a raised-quarter decker, the bulwark is to be reinforced to a standard required for the shell plating in the main ice belt.

2.5 Transverse framing

2.5.1 The increased requirements for transversely framed structures are normally met by the addition of intermediate frames.

2.5.2 Ships with shock enhanced notation transverse intermediate frames are not to be fitted. The ice strengthening requirements are to be met by the use of reduced main frame spacing.

2.5.3 The section modulus of transverse main and intermediate frames (including a width of attached plating equal to *s*), is to be determined in accordance with the following formula:

$$Z = Cs\,\alpha_t\,\beta\,\gamma^2\,\frac{4{,}7}{\sigma_o\,l}\,(3l^2 - h^2)\,K \text{ cm}^3$$

where

d = distance, in metres, measured along the frame from the lower span point to the ice deep waterline or from the upper span point to the ice light waterline, whichever is the lesser. In no case is this distance to be taken greater than $\frac{l}{2}$

h = nominal ice thickness, in metres, for the Ice Class as defined in Vol 1, Pt 1, Ch 2,3.9.14

s, β, γ and σ_o are as defined in 2.4.1

C = 12,5

$K = \frac{4d\,(l - d)}{l^2}$ but is not to be taken greater than 1,0 nor less than 0,3. If the lower span point is above the ice load waterline or the upper span point is below the ice light waterline, then k is to be taken as 0,3

α_t = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in Table 1.2.3

l = span, in metres, measured along a chord at the side between the span points. For definitions of span points, *see* Vol 1, Pt 6, Ch 2,2. Where adjacent main and intermediate frames have different end connections, resulting in different spans, a mean value is to be used.

Table 1.2.3 Longitudinal distribution factor-transverse framing

Ice Class	α_t		
	Forward	Midship	Aft
1AS	1,00	0,87	0,66
1A	0,89	0,68	0,49
1B	0,78	0,49	0,33
1C	0,66	0,31	0,16

2.5.4 The inertia of transverse main and intermediate frames including a width of attached plating equal to *s* is to be determined in accordance with the following formula:

$$I = 4Z\,l \text{ cm}^4$$

Z and l are as defined in 2.5.3.

2.5.5 The cross-sectional shear resisting area of transverse main and intermediate frames is to be determined in accordance with the following formula:

$$A = Cs\,\alpha_t\,\beta\,\gamma^2\,\frac{4{,}7}{\sigma_o}\,K_s \text{ cm}^2$$

where

s, β, γ and σ_o are as defined in 2.4.1

C = 3,75

K_s = 0,5 if the upper span point is below the bottom edge of the main ice belt zone or the lower span point is above the upper edge of the main ice belt zone
= 1,0 for all other cases
α_t is as defined in 2.5.3.

2.5.6 Except as allowed by 2.5.7 to 2.5.9, main and intermediate frames having scantlings as required by 2.5.2 to 2.5.5 are to be continued and bracketed to the first primary longitudinal member outside of the minimum extent of ice framing given in Table 1.2.4 or to the top of floors in ships having a single bottom. In the latter case intermediate frames will require to be bracketed, or otherwise efficiently attached to a gusset plate which is to be fitted at the level of top of floors. The free edge of the horizontal gusset should be suitably supported. In this context a primary longitudinal member is defined as either a deck, inner bottom, margin plate, deep tank top or ice stringer complying with the requirements of 2.8.

Table 1.2.4 Minimum extent of ice framing

Ice Class	Region	Minimum extent of ice framing	
		Above Ice Deep Waterline (mm)	Below Ice Light Waterline (mm)
1AS	Forward (stem to 0,3L_R)	1200	To double bottom or top of floors or 1600 mm whichever is the greater
	Forward (abaft 0,3L_R) and Midship	1200	1600
	Aft	1200	1200
1A, 1B, 1C	Forward (stem to 0,3L_R)	1000	1600
	Forward (abaft 0,3L) and Midship	1000	1300
	Aft	1000	1000

2.5.7 If a primary longitudinal member is fitted within 0,25 m inside a boundary of the minimum extent of ice framing, intermediate frames may be terminated at that member.

2.5.8 If a primary longitudinal member is fitted within 1 m inside a boundary of the minimum extent of ice framing, the intermediate frames may be terminated at that boundary, provided that their ends are attached to the adjacent main frames by a horizontal intercostal member having the same scantlings as the intermediate frames.

2.5.9 If primary longitudinal members are not fitted, or are located more than 1 m inside a boundary of the minimum extent of ice framing, then the intermediate frames may be either:

(a) extended to a primary longitudinal member or equivalent as defined by 2.5.6.

(b) terminated at the boundary of minimum extent of ice framing and attached by a horizontal intercostal member, having the same scantlings as the intermediate frames, to the adjacent main frames. The scantlings of the main frames are to be based on the spacing and span of the main frames. The inertia of the intermediate frames is to be not less than 75 per cent of the main frames.

2.5.10 Except where provided for in 2.5.7 and 2.5.9, the ends of intermediate frames are to be bracketed or otherwise efficiently attached to a primary longitudinal member or are to be attached to adjacent brackets, floors or main frames by a longitudinal flat bar. *See also* 2.7.5.

2.5.11 In twin screw ships, three intermediate frames forward of, and three aft of, the propeller blade tips are to extend to the double bottom.

2.6 Longitudinal framing

2.6.1 The section modulus of longitudinal frames (including a width of attached plating equal to *s*), is to be determined in accordance with the following formula:

$$Z = Cs\,\alpha_l\,\beta\,\gamma^2\,l^2\,\frac{4,7}{\sigma_o}\ \text{cm}^3$$

where
h = ice thickness as defined in 2.2.2
l is as defined in 2.5.3
s = spacing, in mm, of longitudinal frames but need not be taken as greater than 1000h
C = 16,6
α_l = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in Table 1.2.5
β, γ and σ_o are as defined in 2.4.1.

Table 1.2.5 Longitudinal distribution factor-longitudinal framing

Ice Class	α_l		
	Forward	Midship	Aft
1AS	1,00	0,95	0,71
1A	0,90	0,74	0,53
1B	0,80	0,51	0,34
1C	0,68	0,32	0,16

2.6.2 The inertia of longitudinal frames, including a width of attached plating equal to *s*, is to be determined in accordance with the following formula:

$$I = Cs\,\alpha_l\,\beta\,\gamma^2\,l^{2,3}\,\frac{4,7}{\sigma_o}\ \text{cm}^4$$

where
C = 270
Other symbols are as defined in 2.6.1.

2.6.3 The cross sectional shear resisting area of longitudinal frames is to be determined in accordance with the following formula:

$$A = Fs\,\alpha_l\,\beta\,\gamma^2\,l\,\frac{4,7}{\sigma_o}\ \text{cm}^2$$

where

F = 2,5

Other symbols are as defined in 2.6.1.

2.6.4 Where longitudinal framing is adopted, frames satisfying the requirements of 2.6.1 to 2.6.3 are to be fitted within the minimum vertical extent of ice framing in Table 1.2.4.

2.7 Framing – General requirements

2.7.1 The web thickness of ice frames is not, in general, to be less than half that of the attached shell plating with a minimum of 9 mm.

2.7.2 Where a frame intersects a boundary between two of the hull regions defined in 2.2, the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

2.7.3 Main and intermediate frames within the minimum extent of ice framing given in Table 1.2.4 are to be efficiently supported to prevent tripping, e.g. as shown in Fig. 1.2.2. The distance between anti-tripping supports is not to exceed 1500 mm. The extent of anti-tripping supports is to be as given in Table 1.2.6.

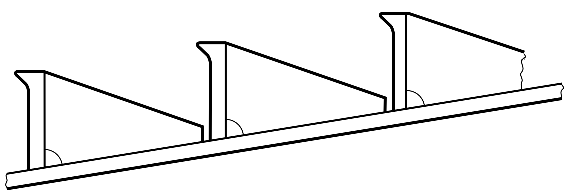


Fig. 1.2.2 Framing support

Table 1.2.6 Extent of anti-tripping supports

Ice Class	Extent of anti-tripping supports
1AS	All regions
1A	Forward and midship region
1B	Forward region
1C	Forward region

2.7.4 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. However, in the case of the aft region for Ice Class 1A, 1B and 1C and the midship region for Ice Class 1B and 1C, consideration will be given to the use of intermittent welding provided the requirements of Vol 1, Pt 6, Ch 6,4.10 are complied with.

2.7.5 Frames are to be effectively attached to supporting structure by brackets. In general, longitudinals are to be connected to both sides of cut-outs in the webs of transverse structure.

2.7.6 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames as required by 2.5.2 or 2.6.3, as appropriate.

2.7.7 Where a bulkhead or deck is fitted instead of an ice strengthened frame, the thickness of the bulkhead or deck adjacent to the shell is normally to be that of the frame for a width sufficient to give an area equal to the frame.

2.8 Primary longitudinal members supporting transverse ice framing

2.8.1 The section modulus of ice stringers or of decks adjacent to hatchways, including a width of attached plating determined in accordance with Vol 1, Pt 6, Ch 2,2.3 and taken about an axis parallel to the plating, is to be determined in accordance with the following formula:

$$Z = C\,\alpha_o\,\beta\,\gamma^2\,l^2\,\frac{4,7}{\sigma_o}\ \text{cm}^3$$

where

l = span, in metres, of the ice stringer or deck adjacent to a hatchway determined in accordance with Vol 1, Pt 6, Ch 2,2.

C = 11 300

α_o = longitudinal distribution factor, dependent on Ice class and longitudinal position, as given in Table 1.2.7

β, γ and σ_o are as defined in 2.4.1.

Table 1.2.7 Longitudinal distribution factor-primary longitudinal members

Ice Class	α_o		
	Forward	Midship	Aft
1AS	1,00	0,98	0,89
1A	0,87	0,75	0,64
1B	0,78	0,64	0,51
1C	0,68	0,53	0,37

2.8.2 The cross sectional shear resisting area of ice stringers or of decks adjacent to hatchways is to be determined in accordance with the following formula:

$$A = C\,\alpha_o\,\beta\,\gamma^2\,l\,\frac{4,7}{\sigma_o}\ \text{cm}^2$$

where

C = 1240

Other symbols are as defined in 2.8.1.

2.8.3 Where the span of a deck adjacent to a hatchway exceeds 10 times the width of the deck strip the scantlings of the deck section may require special consideration to ensure adequate stiffness.

2.8.4 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, *r*, between such stiffening is not to be greater than given according to the following formula:

$$r = \frac{291t^3}{\alpha_o \beta \gamma^2} \text{ mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

Other symbols are as defined in 2.8.1.

2.8.5 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of Vol 1, Pt 6, Ch 6,5.

2.9 Web frames

2.9.1 The section modulus of web frames supporting ice stringers or longitudinal ice frames including a width of attached plating determined in accordance with Vol 1, Pt 6, Ch 2,2 and taken about an axis parallel to the plating is to be determined in accordance with the following formula:

$$Z = Cs\, \alpha_o \beta \gamma^2 l \frac{4,7}{\sigma_o} \text{ cm}^3$$

where

l = span, in metres, of the web frames determined in accordance with Vol 1, Pt 6, Ch 2,2

s = spacing of web frames, in metres

C = 20600

α_o = longitudinal distribution factor as given in Table 1.2.7

β, γ and σ_o are as defined in 2.4.1.

2.9.2 The cross sectional shear resisting area of web frames supporting ice stringers or longitudinal ice frames is to be determined in accordance with the following formula:

$$A = C\, \alpha_o \beta \gamma^2 s \frac{4,7}{\sigma_o} \text{ cm}^2$$

where

C = 1240

α_o and s are as defined in 2.9.1

β, γ and σ_o are as defined in 2.4.1.

2.9.3 Ice stringers are to be bracketed or otherwise efficiently attached to the web frames or transverse bulkheads.

2.9.4 The thickness of the web is generally not to be less than one per cent of the web depth.

2.10 Stem

2.10.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in Fig. 1.2.3 improves the manoeuvrability of the ship in ice.

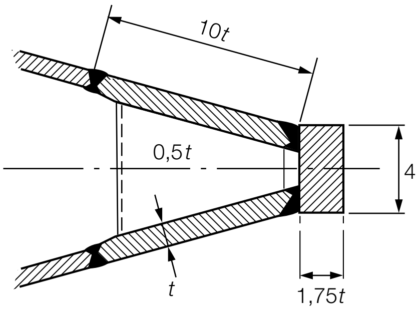


Fig. 1.2.3 A sharp edged stem

2.10.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$$Z = 1500\,(\alpha_o \beta \gamma^2)^{\frac{3}{2}} \text{ cm}^3$$

where

α_o = longitudinal distribution factor for the forward region as given in Table 1.2.3

β and γ are as defined in 2.4.1.

2.10.3 The dimensions of a welded stem constructed as shown in Fig. 1.2.3 are to be determined in accordance with the following formula:

$$t = 31 \sqrt{\alpha_o \beta \gamma^2} \text{ mm}$$

where

t = thickness of the side plates, in mm.

2.10.4 The plate thickness, *t*, of a shaped plate stem or a bulbous bow is to be determined in accordance with the following formula:

$$t = As\, \alpha_p \beta \gamma \sqrt{\frac{4,7}{\sigma_o}} + 2 \text{ mm}$$

where

s = the distance, in mm, between horizontal webs or diaphragm plates having a thickness of at least 0,5*t* mm

A = 0,50

α_p, β, γ and σ_o are as defined in 2.4.1.

2.10.5 The reinforced stem is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by floors, brackets or webs having a thickness of at least 0,5*t* and spaced not more than 600 mm apart.

2.10.6 In bulbous bow constructions the extent of plating having the thickness, *t*, as specified in 2.10.4, below the Ice Light Waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the Ice Light Waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements of 2.4.1.

2.10.7 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of 2.10.2. In addition, vertical ring stiffening will be required for the bulb.

2.10.8 The dimensions of the stem may be tapered to the requirements of Vol 1, Pt 6, Ch 3,5.2 at the upper deck. The connections of the shell plating to the stem are to be flush.

2.10.9 For towing purposes, a mooring pipe with an opening not less than 250 mm by 300 mm having inner surfaces at least 150 mm wide with a rounding radius of not less than 100 mm is to be fitted in the bow bulwark on the centreline. A bitt, or other convenient means of securing the line, is to be dimensioned to withstand the breaking strength of the ship's towline.

2.11 Stern

2.11.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened. *See* Vol 1, Pt 3, Ch 3,2.

2.11.2 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midship region.

2.12 Bossings and shaft struts

2.12.1 Shaftings and sterntubes of ships with two or more propellers are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

2.13 Rudder and steering arrangements

2.13.1 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with Vol 1, Pt 3, Ch 3,2 and 13 as appropriate. Rudder scantlings are to be determined in accordance with Vol 1, Pt 3, Ch 3,2 using the basic stock diameter, δ_s. The speed used in the calculations is to be the service speed or that given in Table 1.2.8, whichever is the greater. When used in association with the speed given in Table 1.2.8, the hull form factor and rudder profile coefficients are to be taken as 1,0.

Table 1.2.8 Minimum speeds

Ice Class	Minimum speed, in knots
1AS	20
1A	18
1B	16
1C	14

2.13.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region in accordance with 2.4.1. For the horizontal and vertical webs the corrosion-abrasion increment, *c*, need not be added.

2.13.3 For Ice Classes 1AS and 1A, the rudder head and the upper edge of the rudder are to be protected against ice pressure by an ice knife, or equivalent.

2.13.4 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

2.13.5 Where an ice class notation is included in the class of a ship, the nozzle construction requirements as defined in Table 3.5.1 in Vol 1, Pt 3, Ch 3,5 are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS	5 mm
1A	4 mm
1B	3 mm
1C	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region as obtained from 2.4.1 taking frame spacing *s* in the formula as 500 mm.

2.13.6 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in 2.13.1. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in Table 1.2.8 or the actual astern speed, whichever is the greater.

2.13.7 Nozzles with articulated flaps will be subject to special consideration.

2.14 Direct calculations

2.14.1 If, as an alternative to the requirements of 2.8 and 2.9, the scantlings of primary longitudinal members and web frames are determined by direct calculation, as permitted by Vol 1, Pt 3, Ch 1,2, then:

(a) the applied ice load may be taken as $775\alpha_o \beta \gamma^2$ kN per metre of ship length evenly distributed over a depth equal to the nominal ice thickness, *h*, for the Ice Class;

(b) the scantlings are to be suitable for the centre of the load depth to be located at any height between the ice load waterline and the ice light waterline;

(c) the scantlings determined in association with (a) and (b) are to be sufficient to ensure that the von Mises-Hencky combined stress does not exceed 90 per cent of the yield stress of the steel.

Section 3
Machinery and engineering systems

3.1 General

3.1.1 Where the notation, Ice Class 1AS, 1A, 1B or 1C is desired, the requirements of this Section, in addition to those for open water service, are to be complied with so far as they are applicable.

3.1.2 This Section is to be read in conjunction with the requirements for Machinery and Engineering Systems in Vol 2, Pt 1, Ch 1 and Ch 2.

3.2 Symbols and definitions

3.2.1 The symbols used in this Section are defined as follows:

A_{WF} = area of the waterline of the bow, in m^2, as shown in Fig. 1.3.1

B = moulded breadth of ship, in metres

D_P = diameter of the propeller, in metres

H_M = thickness of the brash ice in mid channel, in metres

H_F = thickness of the brash layer displaced by the bow, in metres

L_{BOW} = length of bow, in metres, as shown in Fig. 1.3.1

L_{PAR} = length of parallel middle body, in metres, as shown in Fig. 1.3.1

L_{WL} = length of ship at Deep Draught Waterline, in metres

T_{ICE} = maximum ice class draught amidships, in metres, corresponding to the Deep Draught Waterline

Δ = displacement, in tonnes, on the maximum Ice Class draught amidships on the Deep Draught Waterline, *see* 2.2.1. This displacement need not be taken as greater than 80 000 tonnes

α = the angle of the waterline at B/4, *see* Fig. 1.3.1

φ_1 = the rake of the stem at the centreline, as shown in Fig. 1.3.1

φ_2 = the rake of the bow at B/4, as shown in Fig. 1.3.1.

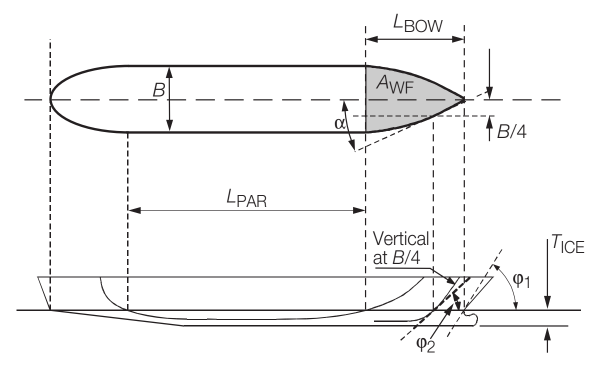


Fig. 1.3.1 Definition of angles, areas and length

3.3 Engine output

3.3.1 **Definition**. The total engine output, P in 3.3.2, is the maximum output the propulsion machinery can continuously deliver to the propulsion system with the propeller(s) operating at the revolutions per minute at the maximum torque for which the system is to be classed. If the output of the machinery is restricted by technical means or by any Regulations applicable to the ship, P, shall be taken as the restricted output.

3.3.2 Required engine output:

(a) For **Ice Class 1AS** and **1A**, the total engine output is not to be less than determined by the following formula:

$$P = K_E \frac{\left(\frac{R_{CH}}{1000}\right)^{\frac{3}{2}}}{D_p} \text{ kW}$$

where K_E is as shown in Table 1.3.1

R_{CH}, in N, is the resistance of the ship in a channel with brash ice and a consolidated layer, using the following equation:

$$R_{CH} = C_1 + C_2 + 845\,(H_F + H_M)^2 \left(B + 1{,}85 H_F - \frac{2H_F}{\tan\Psi}\right) \bullet (0{,}15\cos\varphi_2 + \sin\psi \bullet \sin\alpha) + 42 L_{PAR} H_F^2 + 825 K_d \frac{A_{wf}}{L_{WL}}$$

where

$$K_d = \left[\frac{L_{WL}\,T_{ICE}}{B^2}\right]^3$$

but is not to be taken as more than 20 or less than 5.

$H_F = 0{,}26 + \sqrt{(H_M\,B)}$

H_M = 1,0 for **Ice Classes 1A** and **1AS**.

C_1 and C_2 take into account a consolidated upper layer of the brash ice and can be taken as zero for **Ice Class 1A**. For **Ice Class 1AS**:

$$C_1 = 23 \frac{BL_{PAR}}{\frac{2T_{ICE}}{B} + 1} + (1 + 0{,}021\varphi_1)(45{,}8B + 14{,}7L_{BOW} + 29BL_{BOW})$$

$$C_2 = (1 + 0{,}063\varphi_1)(1530 + 170B) + \left(400 + 480\frac{T_{ICE}}{B}\right)\frac{B^2}{\sqrt{L_{WL}}}$$

$$\psi = \arctan\left[\frac{\tan\varphi_2}{\sin\alpha}\right]$$

(b) For **Ice Class 1B** and **1C**, the total engine output is not to be less than that determined by the following formula and in no case less than 740 kW:

$$P = f_1\, f_2\, f_3\,(f_4\,\Delta + P_o) \text{ kW}$$

where

f_1 = 1,0 for a fixed pitch propeller
= 0,9 for a controllable pitch propeller

$f_2 = \dfrac{\varphi_1}{200} + 0{,}675$ but not more than 1,1

f_2 = 1,1 for a bulbous bow

The product, $f_1\,f_2$, is not to be taken as less than 0,85.

$f_3 = \dfrac{1{,}2B}{\Delta^{1/3}}$ but not less than 1,0

f_4 and P_0 are to be taken as shown in Table 1.3.2:
Δ is as defined in 3.2.

Table 1.3.1 Coefficient of propulsion, K_E

No. of propellers	Propeller type	
	Controllable pitch propeller	Fixed pitch propellers
1	2,03	2,26
2	1,44	1,60
3	1,18	1,31

Table 1.3.2 Values of f_4 and P_0

	1B	1C	1B	1C
	Δ < 30 000 t		$\Delta \geq$ 30 000 t	
f_4	0,22	0,18	0,13	0,11
P_0	370	0	3070	2100

3.4 Materials for shafting

3.4.1 All components of the main propulsion system are to be of steel or other approved ductile material.

3.4.2 For screwshafts in ships intended for the notation **Ice Class 1AS or 1A** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of Vol 1, Pt 2, Ch 5,3.4.12.

3.5 Materials for propellers

3.5.1 Propellers and propeller blades are to be of cast steel or copper alloys.

3.5.2 For steel propellers, the elongation of the material used is to be not less than 19 per cent for a test piece length of 5*d*. Charpy impact tests are to be carried out in accordance with the requirements of Vol 1, Part 2.

3.6 Determination of ice torque

3.6.1 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter defined by ice torque, *M*.

$$M = m\,D^2 \quad \text{kN m}$$

where

m = 21,10 for **Ice Class 1AS**
= 15,69 for **Ice Class 1A**
= 13,04 for **Ice Class 1B**
= 11,96 for **Ice Class 1C**
D = diameter of propeller, in metres.

3.6.2 If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for **Ice Class 1A** is to be used for **Ice Classes 1B** and **1C**.

3.7 Propeller blade sections

3.7.1 The width, *L*, and thickness, *T*, of propeller blade sections are to be determined so that:

(a) at the radius 0,25*D*/2, for solid propellers

$$LT^2 \geq \frac{26\,478\,000}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}\left(27{,}2\,\frac{P}{NR} + 2{,}24M\right)$$

(b) at radius 0,35*D*/2 for controllable pitch propellers

$$LT^2 \geq \frac{21\,084\,300}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}\left(27{,}2\,\frac{P}{NR} + 2{,}35M\right)$$

(c) at the radius 0,6*D*/2

$$LT^2 \geq \frac{9\,316\,320}{\sigma_u\,(0{,}65 + 0{,}7p_r/D)}\left(27{,}2\,\frac{P}{NR} + 2{,}86M\right)$$

where

D = diameter of propeller, in metres
L = length of the expanded cylindrical section of the blade, at the radius in question, in mm
M = ice torque as defined in 3.6.1
N = number of blades
P_r = propeller pitch at the radius in question, for solid propellers, in metres
= 0,7 nominal pitch for controllable pitch propellers, in metres
P = shaft power as defined in Vol 2, Pt 1, Ch 2,3.3
R = propeller speed, in rev/min
T = the corresponding maximum blade thickness, in mm
σ_u = specified minimum tensile strength of the blade material, in N/mm^2.

3.7.2 Where the blade thickness derived from these formulae is less than the blade thickness derived by Vol 2, Pt 4, Ch 1, the latter is to apply.

3.8 Propeller blade minimum tip thickness

3.8.1 The blade tip thickness, *t*, at the radius *D*/2 is to be determined by the following formulae:

Ice Class 1AS

$$t = (20 + 2D)\sqrt{\frac{490}{\sigma_u}} \quad \text{mm}$$

Ice Classes 1A, 1B and **1C**

$$t = (15 + 2D)\sqrt{\frac{490}{\sigma_u}} \quad \text{mm}$$

where D and σ_u are as defined in 3.6 and 3.7 respectively.

3.9 Intermediate blade sections

3.9.1 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by 3.7 and 3.8.

3.10 Blade edge thickness

3.10.1 The thickness of blade edges is to be not less than 50 per cent of the derived tip thickness, t, measured at 1,25t from edge. For controllable pitch propellers this applies only to the leading edge.

3.11 Mechanisms for controllable pitch propellers

3.11.1 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9D/2 in the weakest direction of the blade.

3.12 Keyless propellers

3.12.1 When it is proposed to use keyless propellers, the fit of the propeller boss to the screwshaft will be specially considered.

3.13 Screwshafts

3.13.1 The diameter d_s at the aft bearing of the screwshaft fitted in conjunction with a solid propeller is to be not less than:

$$d_s = 1{,}08 \sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,25D/2, in mm

σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2

σ_u = specified minimum tensile strength of the blade material, in N/mm^2.

3.13.2 The diameter, d_s at the aft bearing of the screwshaft fitted in conjunction with a controllable pitch propeller is to be not less than:

$$d_s = 1{,}15 \sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,35D/2, in mm.

3.13.3 Where the screwshaft diameter as derived by 3.13.1 or 3.13.2 is less than the diameter derived by Vol 2, Pt 3, Ch 2,4.4.3 or 4.4.7 as applicable the latter is to apply.

3.13.4 The shaft may be tapered at the forward end in accordance with Vol 2, Pt 3, Ch 2,4.4.5 or 4.4.6 as applicable.

3.14 Intermediate and thrust shafts

3.14.1 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with Vol 2, Pt 3, Ch 2,4.2.1 and Vol 2, Pt 3, Ch 2,4.3.1 respectively, except for **Ice Class 1AS** ice strengthening where these diameters are to be increased by 10 per cent.

3.15 Reduction gearing

3.15.1 Where gearing is fitted between the engine and the propeller shafting , the gearing is to be in accordance with Vol 2, Pt 3, Ch 1, and is to be designed to transmit a torque, Y_i, determined by the following formula:

$$Y_i = Y + \frac{M I_h u^2}{I_l + I_h u^2} \text{ kN m}$$

where

u = gear ratio = $\dfrac{\text{pinion speed}}{\text{wheel speed}}$

I_h = mass moment of inertia of machinery components rotating at higher speed

I_l = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent of entrained water

(I_h and I_l are to be expressed in the same units)

M = ice torque as defined in 3.6

Y = $9{,}55 \dfrac{P}{R}$.

P and R are as defined in Vol 2, Pt 1, Ch 2, 3.3.

3.16 Starting arrangements

3.16.1 In addition to complying with the requirements of Vol 2, Pt 2, Ch 1,7.1 to 7.5 where applicable, the capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in half an hour for a ship with **Ice Class 1AS** where the propulsion engine has to be reversed for going astern.

3.17 Sea inlet chests and cooling water systems

3.17.1 The cooling water system is to be designed to ensure a supply of cooling water when navigating in ice. For this purpose at least one cooling water inlet chest is to be arranged as follows:

(a) The sea inlet chest is to be situated near the centreline of the ship and well aft if possible.
(b) As guidance for design the volume of the chest shall be about one cubic metre for every 750 kW engine output of the ship including the output of auxiliary engines necessary for the ship's service.
(c) The chest shall be of sufficient height to allow ice to accumulate above the inlet pipe.
(d) A recirculating connection from the cooling water overboard discharge line, capable of full capacity discharge, is to be led to the chest.
(e) The net area through the grating at the shell opening is to be not less than four times the sectional area of the inlet pipe.

Where there are difficulties in meeting the requirements of (b) and (c) two smaller chests may be arranged for alternating intake and discharge of cooling water. The arrangement and situation otherwise shall be as above.

3.17.2 Heating coils may be installed in the upper part of the chest or chests.

3.17.3 Arrangements for circulating water from ballast tanks for cooling purposes may be useful as a reserve in ballast conditions but cannot be accepted as a substitute for sea inlet chests as described in 3.17.1.

3.18 Fire pumps in motor ships

3.18.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the cooling water inlet chest referred to in 3.17.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in Vol 2, Pt 1, Ch 1 and Ch 2.

1.1.2 The requirements of this Chapter are in addition to other relevant Chapters in the Rules for main and auxiliary machinery.

1.1.3 The Rules contained in this Chapter cover machinery arrangements and control systems necessary for operating essential machinery from a (centralized) control station on the bridge under normal seagoing and manoeuvring conditions, but do not signify that the machinery space may be operated unattended.

1.1.4 In general, ships complying with the requirements of this Chapter will be eligible for the machinery class notation **IP** (*see* Vol 1, Pt 1, Ch 2,3.8.2).

1.1.5 The details of control systems will vary with the type of machinery being controlled, and special consideration will be given to each case.

1.1.6 Requirements additional to those in this Chapter may be imposed by the Naval Authority.

1.2 Plans

1.2.1 **Control systems.** Where control systems are applied to essential machinery or equipment the following plans are to be submitted in triplicate:

- Details of operating medium, i.e. pneumatic, hydraulic or electric including standby sources of power.
- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- List of alarm points.
- Test schedule including test facilities provided.

1.2.2 Plans for the control systems of the following machinery are to be submitted:

- Main propelling machinery, including all auxiliaries essential for propulsion.
- Controllable pitch propellers.
- Electric generating plant.
- Evaporating and distilling systems for use with main steam machinery.
- Steam raising plant for essential services.

1.2.3 **Alarm systems.** Details of the overall alarm system linking the machinery space control station with the bridge control station are to be submitted.

1.2.4 **Control stations.** Details of bridge and machinery space control stations are to be submitted, e.g. control panels and consoles.

1.2.5 **Machinery configurations.** Plans showing the general arrangement of the machinery space, together with the layout and configuration of the main propulsion and essential machinery, are to be submitted.

■ *Section 2* Machinery arrangements

2.1 Main propulsion machinery

2.1.1 The main propulsion machinery may be oil engines, turbines or electric motors but the configuration of the propulsion system and its relationship with other essential equipment is to comply with the remaining requirements of this Section.

2.1.2 The main propulsion machinery is to drive one of the generators required by 2.2.2. This generator is to be capable of supplying the essential electrical load under all normal seagoing and manoeuvring conditions.

2.1.3 Standby machinery is to be provided capable of being readily connected to the main propulsion system so as to provide emergency propulsion. This standby machinery is to be capable of connection so as to provide an alternative drive to the generator required in 2.1.2. It need not provide power to both systems simultaneously, *see also* 2.2.2.

2.2 Supply of electric power and essential services

2.2.1 Continuity of electrical power supply and essential services are to be ensured under all normal seagoing and manoeuvring conditions without manual intervention in the machinery space. Methods by which this may be achieved include automatic start-up of generating sets and essential pumps or manual start-up of these services from the bridge.

2.2.2 Generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship even when one generating set or converting set is out of service.

2.3 Controllable pitch propellers

2.3.1 For propulsion systems with controllable pitch propellers a standby or alternative power source for the actuating medium for controlling the pitch of the propeller blades is to be provided.

■ *Section 3* Control arrangements

3.1 Bridge control

3.1.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions when operating on either the main or standby engine(s).

3.1.2 Instrumentation to indicate the following is to be fitted on the bridge and at any other station from which the propulsion machinery may be controlled:
(a) Propeller speed.
(b) Direction of rotation of the propeller for a fixed pitch propeller.
(c) Pitch position for a controllable pitch propeller.
(d) Direction and an indication representative of the magnitude of thrust.
(e) Clutch position, where applicable.

3.1.3 An alarm is to operate in the event of a failure of the power supply to the bridge control system.

3.1.4 Means, independent of the bridge control system, are to be provided on the bridge to enable the watchkeeping officer to stop the main propulsion machinery in an emergency.

3.2 Alarm system

3.2.1 An alarm system is to be provided to indicate faults in essential machinery and control systems in accordance with this Chapter.

3.2.2 Machinery faults are to be indicated at the control stations on the bridge and in the machinery space.

3.2.3 In the event of a machinery fault occurring, the alarm system is to be such that the watchkeeping officer on the bridge is made aware of the following:
(a) A machinery fault has occurred.
(b) The machinery fault is being attended to.
(c) The machinery fault has been rectified. (Alternative means of communication between the bridge control station and the machinery control station may be used for this function.)

3.2.4 The alarm system should be designed with self-monitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

3.2.5 The alarm system should be capable of being tested during normal machinery operation.

3.2.6 Failure of the power supply to the alarm system is to be indicated as a separate fault alarm.

3.2.7 Alarm indication is to be both audible and visual. If arrangements are made to silence audible alarms they are not to extinguish visual alarms.

3.2.8 The acceptance of an alarm on the bridge is not to silence the audible alarm in the machinery space.

3.2.9 Machinery alarms should be distinguishable from other audible alarms, e.g. fire, carbon dioxide.

3.2.10 Acknowledgement of visual alarms is to be clearly shown.

3.2.11 If the audible alarm has been silenced and a second fault occurs before the first has been rectified, the audible alarm is again to operate. To assist in the detection of transient faults which are subsequently self-correcting, fleeting alarms should lock-in until accepted.

3.2.12 Arrangements should be made to enable alarm lights on the bridge to be dimmed as required.

3.3 Communication

3.3.1 At least two means of communication are to be provided between the bridge and the control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply.

3.3.2 The bridge, machinery space control station and any other control position from which the propulsion machinery can be controlled are to be fitted with means to indicate which station is in command.

3.3.3 Changeover between control stations is to be arranged so that it may only be affected with the acceptance of the stations taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

3.4 Engine starting safeguards

3.4.1 Where it is possible to start a main propulsion or auxiliary oil engine from the bridge, an indication that sufficient starting air pressure is available is to be provided on the bridge.

3.4.2 The number of automatic consecutive attempts which fail to produce a start is to be limited to safeguard sufficient starting air pressure, or, in the case of electric starting, a sufficient charge level in the batteries.

3.4.3 An alarm is to be provided for low starting air pressure, set at a limit which will still permit engine starting operations.

3.4.4 Where propulsion or auxiliary engines are started from the bridge, interlocks are to be provided to prevent starting of the engine under conditions which could hazard the machinery. These are to include 'turning gear engaged', 'low lubricating oil pressure', 'shaft brake engaged' and where machinery is not available due to maintenance or repairs.

3.5 Operational safeguards

3.5.1 Means are to be provided to prevent the machinery and shafting being subjected to excessive torque or other detrimental mechanical and thermal overloads.

3.5.2 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

3.5.3 For ships propelled by steam turbines the risk of thermal distortion of the turbines is to be prevented by automatic steam spinning when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to operate on the bridge and in the machinery space when the shaft has been stopped for two minutes.

3.5.4 In the case of lubricating oil systems for main propulsion and standby engine(s), the engine(s) is to be stopped automatically on failure of the lubricating oil supply. The circuit and sensor employed for this automatic shut-down are to be additional to the alarm circuit and sensor required by Vol 2, Pt 7, Ch 3,8.3. Where means are provided to over-ride the automatic shut-down required by this paragraph, the arrangements are to be such as to preclude inadvertent operation. Visual indication of operation of the over-ride is to be fitted.

3.5.5 In the case of oil engines, oil mist monitoring is to be provided for crankcase protection where arrangements are fitted to over-ride the automatic stop for failure of the lubricating oil supply.

3.5.6 Boilers with automatic controls which under normal operating conditions do not require any manual intervention by the operators are to be provided with safety arrangements which automatically shut-off the oil fuel to all the burners in the event of either low water level or combustion air failure. Oil fuel is to be shut off automatically to any burner in the event of flame failure.

3.5.7 Arrangements are to be provided to automatically stop propulsion gas turbines for the following fault conditions:
(a) Overspeed (*see* Vol 2, Pt 2, Ch 2,8).
(b) High exhaust temperature (*see* Vol 2, Pt 2, Ch 2,8).
(c) Flame failure, or
(d) Excessive vibration.

3.5.8 Where standby pumps are arranged to start automatically in the event of low discharge pressure from the working pump an alarm is to be given to indicate when the standby pump has started.

3.6 Automatic control of essential services

3.6.1 All control systems for essential services are to be stable throughout the operating range of the main propulsion machinery.

3.6.2 The temperature of the following is to be automatically controlled within normal operating limits:
Oil engines:
(a) Lubricating oil to the main engine and/or auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Piston coolant, where applicable.
(d) Cylinder coolant main and auxiliary engines, where applicable.
(e) Fuel valve coolant, where applicable.
Steam plant:
(a) Lubricating oil to main engine and/or auxiliary engines.
(b) Oil fuel to burners – temperature or viscosity.
(c) Superheated steam.
(d) External de-superheated steam.
Gas turbines:
(a) Lubricating oil to main engine and auxiliary engines.
(b) Oil fuel – temperature or viscosity.
(c) Exhaust gas.

3.6.3 The pressure of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Superheated steam.
(b) Oil fuel.
(c) External de-superheated steam system(s).
(d) Gland steam.
(e) Reduced steam ranges.

3.6.4 The level of the following is to be automatically controlled within normal operating limits:
Steam plant:
(a) Boiler drum level.
(b) De-aerator level.
(c) Condenser level.

3.6.5 Boilers essential for the propulsion of the vessel are to be provided with an automatic combustion control system.

3.7 Local control

3.7.1 The arrangements are to be such that essential machinery can be operated with the system of bridge control or any automatic controls out of action. Alternatively, the control systems should have sufficient redundancy so that failure of the control equipment in use does not render essential machinery inoperative.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter apply to naval ships with installed dynamic positioning systems and are additional to those applicable in other Parts of these Rules.

1.1.2 A ship provided with a dynamic positioning system in accordance with these Rules will be eligible for an appropriate class notation.

1.1.3 Requirements, additional to these Rules may be imposed by the Naval Authority.

1.1.4 For the purpose of these Rules, dynamic positioning means the provision of a hydro-dynamic system with automatic and/or manual control capable of maintaining the heading and position of the ship during operation within specified limits and environmental conditions.

1.1.5 For the purpose of these Rules, the area of operation is the specified allowable position deviation from a set point, *see* 1.3.2.

1.1.6 Special consideration will be given where the dynamic positioning system is used primarily for purposes other than position keeping, e.g. track following.

1.2 Classification notations

1.2.1 Ships complying with the requirements of this Chapter will be eligible for one of the following class notations, as defined in Vol 1, Pt 1, Ch 2:

DP(CM) *See* Section 2.
DP(AM) *See* Section 3.
DP(AA) *See* Section 4.
DP(AAA) *See* Section 5.

1.2.2 The class notation may be supplemented with a Performance Capability Rating (PCR). This rating indicates the calculated percentage of time that a ship is capable of maintaining heading and position under a standard set of environmental conditions (North Sea). *See* Section 6.

1.2.3 Where a **DP** notation is not requested, dynamic positioning systems are to be installed in accordance with the requirements of Section 2 as far as is practicable.

1.3 Information and plans required to be submitted

1.3.1 The information and plans specified in 1.3.2 to 1.3.7 are to be submitted in triplicate. The Operation Manuals specified in 1.3.8 are to be submitted in a single set.

1.3.2 Details of the limits of the area of operation and heading deviations together with proposals for redundancy and segregation provided in the machinery, electrical installations and control systems are to be submitted. These proposals are to take account of the possible loss of performance capability should a component fail or in the event of fire or flooding, *see also* 1.3.6 and Sections 4 and 5.

1.3.3 Where a common power source is utilised for thrusters, details of the total maximum load required for dynamic positioning are to be submitted.

1.3.4 Plans of the following together with particulars of ratings in accordance with the relevant Parts of the Rules are to be submitted for:

(a) Prime movers, gearing, shafting, propellers and thrust units.
(b) Machinery piping systems.
(c) Electrical installations.
(d) Pressure vessels for use with dynamic positioning system.

1.3.5 Plans of control, alarm and safety systems including the following are to be submitted:

(a) Functional block diagrams of the control system(s).
(b) Functional block diagrams of the position reference systems and the environmental sensors.
(c) Details of the electrical supply to the control system(s) the position reference system(s) and the environmental sensors.
(d) Details of the monitoring functions of the controllers, sensors and reference system together with a description of the monitoring functions.
(e) List of equipment with identification of the manufacturer, type and model.
(f) Details of the control stations, e.g. control panels and consoles, including the location of the control stations.
(g) Test schedules (for both factory acceptance and sea trials) that are to include the methods of testing and the test facilities provided.

1.3.6 For assignment of **DP(AA)** or **DP(AAA)** notation, a Failure Mode and Effect Analysis (FMEA) is to be submitted, demonstrating that adequate segregation and redundancy of the machinery, the electrical installation and the control systems have been achieved in order to maintain position in the event of keeping capability in the event of equipment failure (*see* Section 4); or fire or flooding, *see* Section 5.

1.3.7 The following information is to be submitted for assignment of a PCR:
(a) Lines plan.
(b) General arrangement.
(c) Details of thruster arrangement.
(d) Thruster powers and thrusts.

1.3.8 Operation Manuals, including details of the dynamic positioning system operation, installation of equipment, maintenance and fault finding procedures, together with a section on the procedure to be adopted in emergency, are to be submitted. A copy of the manual is to be placed and retained on board the ship.

■ *Section 2*
Class notation DP(CM)

2.1 General

2.1.1 For assignment of **DP(CM)** notation the requirements of 2.1.2 and 2.2 to 2.4 are to be complied with.

2.1.2 Control engineering systems, electrical and piping installations and machinery items are to be designed, constructed, installed and tested in accordance with the relevant requirements of Vol 2, Pt 7, 9 and 10.

2.2 Thrust units

2.2.1 Thruster installations are to be designed, constructed, installed and tested in accordance with the requirements of Vol 2, Pt 4, Ch 3, as applicable.

2.2.2 Thruster installations are to be designed to minimise potential interference with other thrusters, sensors, hull or other surfaces which could be encountered in the service for which the ship is intended.

2.2.3 Thruster intakes are to be located at sufficient depth to reduce the possibility of ingesting floating debris and vortex formation.

2.2.4 The response and repeatability of thrusters to changes in propeller pitch or propeller speed/direction of rotation are to be suitable for maintaining the area of operation and heading within specified limits.

2.3 Electrical systems

2.3.1 This Section applies to the electrical generation and distribution system associated with the Dynamic Positioning System whether this generating system is dedicated to the DP system or forms a central generating arrangement for all loads on the vessel.

2.3.2 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Vol 2, Pt 10, Ch 1 together with the requirements 2.3.3 to 2.3.12.

2.3.3 Where thruster units are electrically driven the relevant requirements, including surveys, of Vol 2, Pt 10, Ch 1,15 are to be complied with.

2.3.4 Essential services are those defined in Vol 2, Pt 10, Ch 1,1.5, as applicable, together with thruster auxiliaries, computers, generator and thruster control equipment, reference systems, environmental sensors and electrically driven thruster units.

2.3.5 The number and rating of generator sets, transformers and converter equipment are to be sufficient to ensure the operation of essential services even when one generating set, transformer or converter equipment is out of action.

2.3.6 For electrically driven thruster systems the generator rating is to be determined by the maximum dynamic positioning load together with the maximum ancillary load.

2.3.7 There are to be arrangements to prevent overloading of the running generator(s). The tripping of non-essential loads and the temporary reduction in the load demands of electrically driven thrusters may form part of these arrangements.

2.3.8 An alarm is to be initiated when the total electrical load exceeds a preset percentage of the running generator(s) capacity. This alarm is to be adjustable between 50 and 100 per cent of the running capacity and is to be set with regard to the number of generators in service and the effect of the loss of any one generator.

2.3.9 On loss of power due to the failure of the operating generator(s) there is to be provision for the automatic starting and connection to the switchboard of a standby set and the automatic sequential restarting of essential services.

2.3.10 Any loads that require an uninterrupted electrical power supply are to be provided with UPS systems having a capacity for a minimum of 30 minutes' operation following loss of the main supply.

2.3.11 An indication of the absorbed power and the available on-line generating capacity is to be provided at the main dynamic positioning control station.

2.3.12 Essential services are to be served by individual feeders. Services that are duplicated are to be supplied from opposite sides of the main switchboard busbar circuit breaker and their cables are to be separated throughout their length as widely as practical and without the use of common feeders, transformers, converters, protective devices or control panels and circuits.

2.4 Control stations

2.4.1 Control stations from which the dynamic positioning system may be operated are to be designed in accordance with sound ergonomic principles, and are to be provided with sufficient instrumentation to provide effective control and indicate that the systems are functioning correctly. Colour schemes and screen layouts are to be selected such that necessary information is readily available and clearly displayed. *See also* Vol 2, Pt 9, Ch 1,2.9 for general ergonomic requirements.

2.4.2 Control station(s) are to be located such that the operator has a good view of the ship's exterior limits and surrounding area.

2.4.3 Indication of the following is to be provided at each station from which it is possible to control the dynamic positioning system:
(a) The heading and location of the ship relative to the desired reference point or course.
(b) Vectorial thrust output, individual and total.
(c) Operational status of position reference systems and environmental sensors.
(d) Environmental conditions, e.g. wind speed and direction.
(e) Availability status of standby thruster units.

2.4.4 At least one position reference system, heading reference sensor and wind sensor are to be provided to ensure that the specified area of operation and heading can be effectively maintained.

2.4.5 Position reference systems are to incorporate measurement techniques suitable for the service conditions for which the ship is intended.

2.4.6 Where necessary for the correct functioning of a position reference system, a vertical reference sensor is to be provided to correct for the pitch and roll of the ship. There are to be at least as many vertical reference units as there are associated position reference systems.

2.4.7 Alarms, in accordance with the requirements of Vol 2, Pt 9, Ch 1,2.3, are to be provided for the following fault conditions as applicable:
(a) When the ship deviates from the area of operation.
(b) When the heading exceeds the allowable deviation.
(c) Position reference system fault (for each reference system).
(d) Heading reference sensor fault.
(e) Vertical reference sensor fault.
(f) Wind sensor fault.
(g) Taut wire excursion limit.
(h) Automatic changeover to a standby position reference system or environmental sensor.

2.5 Control system

2.5.1 A centralised remote manual control system is to be provided such that changes in the vectorial thrust output may be readily effected by a single operator action.

2.5.2 Suitable processing and comparative techniques are to be provided to validate the control system inputs from position and other sensors. Abnormal signal errors revealed by the validity checks are to operate alarms.

2.5.3 The control system for dynamic positioning operation is to be stable throughout its operational range and is to meet the specified performance and accuracy criteria.

2.5.4 Automatic controls are to be provided to maintain the heading of the ship within specified limits.

2.5.5 The allowable deviation from the desired heading is to be adjustable, but should not exceed the specified limits, *see* 1.1.4. Arrangements are to be provided to fix and identify the set point for the desired heading.

2.5.6 Alarms, in accordance with the requirements of Vol 2, Pt 9, Ch 1,2.3, are to be provided for the following fault conditions:
(a) Control computer system fault.
(b) Automatic changeover to a standby control computer system, as applicable, *see* 4.1.7.

■ *Section 3* **Class notation DP(AM)**

3.1 Requirements

3.1.1 For assignment of **DP(AM)** notation, the applicable requirements of Section 2, together with 3.1.2 to 3.1.7 are to be complied with.

3.1.2 An automatic and a manual control system are to be provided and arranged to operate independently so that failure in one system will not render the other system inoperative. Arrangements for manual control are to satisfy the requirements of Section 2 when the automatic system is inoperative.

3.1.3 At least two position reference systems suitable for the intended service conditions and incorporating different measurement techniques, are to be provided and arranged so that a failure in one system will not render the other system inoperative. Special consideration will be given where the use of different techniques would not be practicable during DP operations.

3.1.4 At least two heading reference sensors and two wind sensors are to be provided and arranged so that a failure of one sensor will not render the other sensor(s) inoperative.

3.1.5 In the event of a single failure of a position reference, heading reference, or wind sensor, the control systems are to continue operating on signals from the remaining sensors without manual intervention.

3.1.6 The area of operation is to be adjustable, but is not to exceed the specified limits based on a percentage of water depth, or as applicable, a defined absolute or relative surface movement. Arrangements are to be provided to fix and identify the set point for the area of operation.

3.1.7 In the event of failure of any single thruster, the ship is to be capable of maintaining its area of operation and desired heading in the environmental conditions in which the DP system is intended to operate.

■ *Section 4*
Class notation DP(AA)

4.1 Requirements

4.1.1 For assignment of **DP(AA)** notation the applicable requirements of Sections 2 and 3, together with 4.1.2 to 4.1.9 are to be complied with.

4.1.2 Power, control and thruster systems and other systems necessary for the correct functioning of the DP system are to be provided and configured such that a fault in any active component or system will not result in a loss of position. This is to be verified by means of a FMEA, *see* 1.3.6. Such components may include, but are not restricted to, the following:

Prime movers (e.g. auxiliary engines).
Generators and their excitation equipment.
Gearing.
Pumps.
Fans.
Thrusters.
Valves (where power actuated).

4.1.3 Cables, pipes and other components essential for correct functioning of the DP system are to be located and protected, where necessary, such that the risk of fire or mechanical damage is minimised.

4.1.4 The generation and distribution arrangements are to be such that no single fault will result in the loss of more than 50 per cent of the generating capacity or of any duplicated essential services. However, when electrically driven thrusters are employed, a reduction in position keeping capability may be accepted, but this is not to result in a loss of position in the environmental conditions in which the DP system is intended to operate.

4.1.5 For electrically driven thruster systems, provision is to be made for the automatic starting, synchronising and load sharing of a non-running generator before the load reaches the alarm level required by 2.3.8.

4.1.6 Two automatic control systems are to be provided and arranged to operate independently so that failure in one system will not render the other system inoperative.

4.1.7 Control systems are to be arranged such that, in the event of failure of the working control system, the standby system takes control automatically without manual intervention and without any adverse effect of the ship's station keeping performance.

4.1.8 At least three position reference systems incorporating at least two different measurement techniques provided and are to be arranged so that a failure in one system will not render the other systems inoperative.

4.1.9 At least three heading reference sensors are to be provided and arranged so that a failure of one sensor will not render the other sensor(s) inoperative.

■ *Section 5*
Class notation DP(AAA)

5.1 Requirements

5.1.1 For assignment of **DP(AAA)** notation the applicable requirements of Sections 2, 3 and 4, together with 5.1.2 to 5.1.12 are to be complied with.

5.1.2 The DP system is to be arranged such that failure of any component or system necessary for the continuing correct functioning of the DP system, or the loss of any one compartment as a result of fire or flooding will not result in a loss of position. This is to be verified by means of a FMEA, *see* 1.3.6.

5.1.3 Thruster units are to be installed in separate machinery compartments, separated by a watertight A–60 class division.

5.1.4 Generating sets, switchboards and associated equipment are to be located in at least two compartments separated by an A–60 class division, so that at least half of the equipment will be available following a fire or similar fault in one of the compartments. If the equipment is located below the operational waterline, the division is also to be watertight. There is to be provision to connect the switchboard sections together by means of circuit breakers.

5.1.5 Duplicated cables and pipes for services essential for the correct functioning of the DP system are not to be routed through the same compartments. If this is not practicable, then they are to be carried in A–60 protected ducts. The termination arrangements are also to take due account of the degree of protection. Alternative arrangements will be considered.

5.1.6 An additional/emergency automatic control unit is to be provided at an emergency control station, in a compartment separate from that for the main control station, and is to be arranged to operate independently from the working and standby control units required by 4.1.7.

5.1.7 Arrangements are to be provided such that in the event of a failure of the working and standby control units a smooth transfer of control to the emergency control unit may be effected from the emergency control station by manual means.

5.1.8 Arrangements are to be provided at the emergency control station so that changes in the resultant vectorial thrust output may be readily effected by a single operator action.

5.1.9 The control/indication unit of one of the position reference systems required by 4.1.8 is to be located at the emergency control station. A repeater control/indication unit from this system is to be located at the main control station.

5.1.10 One of the heading reference sensors required by 4.1.9 is to be located at the emergency control station.

5.1.11 One wind sensor is to directly supply the additional/emergency control unit.

5.1.12 The additional/emergency control unit is to be supplied from its own independent UPS, *see* 2.3.10.

■ *Section 6* Performance Capability Rating (PCR)

6.1 Requirements

6.1.1 For assignment of a Performance Capability Rating (PCR), a calculation will be carried out using the information specified in 1.3.7.

6.1.2 Two rating numerals are calculated:
(a) The first numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with all thrusters operating.
(b) The second numeral represents the percentage of time that the ship can remain on station when subjected to a set of standard environmental conditions (North Sea fully developed) with the most effective thruster being inoperative.

A typical rating might be (95), (70).

6.1.3 In calculating the PCR the following parameters are considered:
(a) Thruster force vectors.
(b) Thruster/thruster, thruster/hull and thruster/current interactions.
(c) Sea current loads on the ship.
(d) Wind force on the ship.
(e) Wave drift force on the ship.

6.1.4 Where the ship has been subject to alteration or addition, which may affect the performance characteristics of the DP system, the PCR is to be recalculated.

■ *Section 7* Testing

7.1 General

7.1.1 Control units are to be surveyed at the manufacturer's works and are to be tested to the approved test schedule to the Surveyor's satisfaction, *see* 1.3.5(g).

7.1.2 Before a new installation (or any existing installation, which has been subject to alteration or addition which may affect the performance characteristics of the system) is put into service, sea trials are to be carried out to the approved schedule and to the Surveyor's satisfaction, *see* 1.3.5(g).

7.1.3 The suitability of the dynamic positioning system is to be demonstrated during sea trials, observing the following:
(a) Response of the system to simulated failures of major items of control and mechanical equipment, including loss of electrical power, verifying the findings of the FMEA where required.
(b) Response of the system under a set of predetermined manoeuvres for changing:
  (i) location of area of operation; and
  (ii) heading of the ship.
(c) Continuous operation of the system over a period of four to six hours.

7.1.4 Three copies of the dynamic positioning system sea trial test schedules, as required by 1.3.5(g), each signed by the Naval Authority, Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed and retained on board the ship and the others submitted to LR and Naval Authority.

7.1.5 Records and data regarding the performance capability of the dynamic positioning system are to be maintained on board the ship and are to be made available at the time of the Annual Survey. *See* Vol 1, Pt 1, Ch 3,2.3.12.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of this Chapter apply to naval ships where an optional class notation for periodic operation of the ship under the supervision of a single watchkeeper on the bridge is requested and are additional to those applicable in other Parts of the Rules.

1.1.2 The requirements of this Chapter are based on the understanding that the *International Regulations for Preventing Collisions at Sea* and all other relevant Regulations relating to Radio Communications and Safety of Navigation required by Chapters IV and V respectively of SOLAS are complied with.

1.1.3 Requirements additional to those in this Chapter may be imposed by the Naval Authority.

1.1.4 The requirements of this Chapter are framed on the understanding that contingency plans for emergencies are specified and the conditions under which one man watch is permitted are clearly defined in an operations manual which is acceptable to the Naval Authority.

1.1.5 In general, ships complying with the requirements of this Chapter will be eligible for the notation **NAV1**.

1.1.6 Where a ship is not intended to operate a periodic one man watch, but a notation to indicate a superior standard of equipment and bridge design is desired, the requirements of 4.2 and 4.3 may be relaxed and, in general, ships complying with the remainder of this Chapter will be eligible for the notation **NAV**.

1.1.7 Section 5 of this Chapter states additional requirements which apply where the navigational functions are integrated. In general, ships complying with the requirements of Section 5 will be eligible for the notation **IBS**. (*See* Vol 1, Pt 1, Ch 2,3.8.4.)

1.2 Information and plans required to be submitted

1.2.1 The following information and plans are to be submitted in triplicate:

- Details of the intended area of operation of the ship.
- List of navigational equipment detailing manufacturer, and model and Naval Authority approval (where applicable).
- Functional block diagrams and descriptions of the navigational equipment, internal communication systems and watch safety system indicating their relationship to each other.
- Details of the electrical power supplies to the navigational equipment, internal communications systems, watch safety system, and clear view arrangements.
- A general arrangement of the vessel showing the fields of vision from the bridge.
- A general arrangement of the bridge and wheelhouse showing the positions of consoles, panels, handrails, seating, windows and clear view arrangements.
- A profile view of the wheelhouse detailing the inclination of windows, heights of upper and lower edges of windows, and dimensions of consoles.
- Detailed arrangements of consoles and panels showing the layout of equipment.
- Test schedules which should include methods of testing and test facilities provided.

1.3 Definitions

1.3.1 The following definitions are applicable to these Rules:

Workstation:
A position at which one or several tasks, constituting a particular activity is carried out.

Navigation workstation:
A workstation at which the navigator may carry out all tasks relevant for deciding, executing and maintaining course and speed in relation to waters and traffic. The instrumentation and controls at the navigation workstation should allow the navigator to:

- analyse the traffic situation;
- monitor position, course, track, speed, time, propeller revolutions and pitch, rudder angle, depth of water, rate of turn, and wind speed and direction;
- alter course and speed;
- effect internal and external communications;
- give and receive sound signals;
- control navigational lights;
- monitor and acknowledge navigational alarms;
- confirm his well-being and watch-keeping awareness;
- record navigational data.

Main steering position:
That part of the navigation workstation where those controls and instrumentation relevant to controlling the ship's course are located.

Conning position:
A place on the bridge which is used by navigators when commanding, manoeuvring and controlling a ship.

Voyage planning workstation:
A workstation at which the navigator may carry out the following tasks without affecting the actual navigation of the vessel:

- examine and update charts and other relevant documentation;
- plan a voyage as a series of waypoints, courses, speeds and turns;
- calculate an estimated time of arrival at various points on the voyage;
- determine and plot the ship's position.

■ *Section 2* **Physical conditions**

2.1 Bridge and wheelhouse arrangement

2.1.1 The bridge configuration, arrangement of consoles and equipment location are to be such as to enable the officer of the watch to perform navigational duties and other functions allocated to the bridge as well as maintain an effective lookout.

2.1.2 Equipment and associated displays and indicators are to be sited at clearly defined workstations.

2.1.3 Consoles, including the chart table, are to be positioned so that the instrumentation they contain is mounted in such a manner as to face a person looking forward. As far as practicable, operating surfaces are to be normal to the operator's line of sight.

2.1.4 From other workstations it is to be possible to monitor the navigation workstation and to maintain an effective lookout.

2.1.5 The main access to the bridge is to be by means of an internal stairway. Secondary external access is also to be provided.

2.1.6 Clear passage of at least 700 mm width is to be available to allow movement around the bridge with a minimum of inconvenience. Particular attention is to be paid to the following routes which are to be as direct as possible:
(a) from wing to wing;
(b) between the internal entrance to the bridge and the route in (a).
Space necessary for operating at a workstation is to be considered as part of the workstation and is not to be part of the passageway.

2.1.7 The clear height between the wheelhouse deck surface covering and the underside of the deckhead (or the lower edge of deckhead mounted equipment) is to be at least 2100 mm in open areas, passageways and at standing workstations.

2.1.8 Toilet facilities are to be provided on or adjacent to the bridge.

2.2 Environment

2.2.1 The bridge is to be free of physical hazards to personnel. There are to be no sharp edges or protuberances and wheelhouse, bridge wing and upper bridge decks are to be free of trip hazards and have non-slip surfaces whether wet or dry.

2.2.2 Sufficient hand-rails or equivalent are to be fitted inside the wheelhouse and around workstations to enable personnel to move or stand safely in bad weather. Protection of stairway openings is to be given special consideration.

2.2.3 Provision for seating is to be made in the wheelhouse. Means for securing the seating are to be provided having regard to storm conditions.

2.2.4 Glare and reflections from surfaces are to be minimized. In this respect walls, ceilings, consoles, chart tables and other major fittings are to be provided with a suitable low reflective finish. Arrangements are to be provided to prevent the obscuration of information presented on visual display units and instruments which are fitted with transparent covers.

2.2.5 Entrance doors to the wheelhouse are to be securable from the inside, and operable with one hand. Bridge wing doors are not to be self-closing, and are to be provided with means to hold them open.

2.2.6 An adequate air conditioning or mechanical ventilation system together with sufficient heating according to climatic conditions is to be provided in order to maintain the temperature of the wheelhouse within the range of 14ºC to 30ºC. Control of this system is to be provided in the wheelhouse.

2.2.7 The noise level on the bridge is not to interfere with verbal communication, mask audible alarms, or be uncomfortable to bridge personnel. In this respect the ambient nose level in the wheelhouse in good weather is not to exceed 65 dB(A).

2.2.8 A sound reception system or alternative means is to allow external sound signals to be heard and their direction determined within the wheelhouse.

2.3 Lighting

2.3.1 The level of lighting is to enable bridge personnel to perform all bridge tasks, including maintenance and chart and office work, by day and night. Controls, indicators, instruments, keyboards, etc., on the bridge are to be capable of being seen in the dark either by means of internal lighting within the equipment or the wheelhouse lighting system.

2.3.2 All illumination and lighting of instruments, keyboards and controls is to be adjustable down to zero, except the lighting of alarm indicators and the controls of dimmers which are to remain readable.

2.3.3 Two separate circuits are to be provided for wheelhouse lighting such that failure of any one of the circuits does not leave the space in darkness. *See* Vol 2, Pt 10, Ch 1,5.7.

2.3.4 Emergency lighting is to be provided for the wheelhouse, stairways and exits. *See* Vol 2, Pt 10, Ch 1,3.

2.3.5 Lighting used in areas and at items of equipment requiring illumination whilst the ship is navigating is to be such that night vision is not impaired, e.g. red lighting. Such lighting is to be arranged so that it cannot be mistaken for a navigation light by another ship.

2.3.6 In order to avoid possible confusion in colour discrimination, red lighting is not to be fitted over chart tables.

2.3.7 To avoid unnecessary light sources in the front area of the bridge, only instruments necessary for the safe navigation and manoeuvring of the ship are to be located in this area.

2.3.8 Means are to be provided to prevent the sudden flooding of light onto the bridge from alleyways, accommodation areas and the chart table area.

2.3.9 Deck and superstructure lights which may impair safe navigation are to be controlled from the bridge.

2.3.10 Each navigation light is to be provided with an audible and visual alarm to indicate failure of the light. *See* Vol 2, Pt 10, Ch 1,14.5.

2.3.11 Means are to be provided to test alarm and indicator lamps.

2.4 Windows

2.4.1 All wheelhouse windows are to be constructed of shatterproof toughened glass having a strength commensurate with the degree of exposure of the bridge to storm conditions and complying with a recognized National or International Standard, e.g. ISO 3254 *Shipbuilding and marine structures – Toughened safety glass for rectangular windows*.

2.4.2 Windows are to be as wide as possible and divisions between them are to be kept to a minimum. No division is to be positioned immediately forward of any workstation.

2.4.3 To reduce reflections from internal lighting, etc., the bridge windows are to be inclined from the vertical plane top out, at an angle of not less than 10° and not more than 25º. Alternative arrangements will be specially considered.

2.4.4 The height of the lower edge of the front windows is to allow a forward view over the bow for a person at the navigation workstation and is not to obstruct any of the required fields of vision, *see* 2.5. In this respect the height of the lower edge of the front windows above the deck is to be kept as low as possible and as far as practicable is not to be more than 1000 mm above the deck surface.

2.4.5 The upper edge of the front windows is to allow a forward view of the horizon for a person with an eyeheight of 1800 mm at the conning position when the ship is pitching in heavy seas and as far as practicable is not to be less than 2000 mm above the deck surface.

2.4.6 Clear views through the windows in front of the conning position, navigation workstation, and where applicable bridge wings are to be provided at all times regardless of weather conditions. At least two windows are to provide such a view.

2.4.7 To ensure a clear view in bright sunshine, sunscreens with minimum colour distortion are to be provided. Such screens are to be readily removable and not permanently installed. Polarized and tinted windows are not to be fitted.

2.4.8 Heavy duty wipers, preferably provided with an interval function and a fresh water wash, are to be fitted.

2.4.9 Efficient cleaning, de-icing and de-misting systems are to be fitted.

2.4.10 Suitable safe external access arrangements fitted under the bridge windows are to be provided to enable cleaning and maintenance in the event of failure of the above systems.

2.5 Fields of vision

2.5.1 It is to be possible to observe all objects necessary for navigation, including other traffic and navigation marks, in any direction from inside the wheelhouse. In this respect there is to be a field of view around the vessel of 360º obtained by an observer moving within the confines of the wheelhouse.

2.5.2 The view of the sea surface from the conning position and the navigation workstation is not to be obscured by more than two ship lengths, or 500 m, whichever is less, forward of the bow to 10º on either side irrespective of the ship's draught and trim.

2.5.3 Blind sectors caused by obstructions outside of the wheelhouse forward of the beam obstructing the view of the sea surface as seen from the conning position and the navigation workstation are not to exceed 10° each. The total arc of blind sectors is not to exceed 20° and the clear sector between blind sectors shall be at least 5°. However in the view described in the preceding paragraph each individual blind sector is not to exceed 5º.

2.5.4 The horizontal field of vision from the conning position and the navigation workstation is to extend over an arc from more than 22,5º abaft the beam on one side, through forward, to more than 22,5º abaft the beam on the other side. *See* Fig. 4.2.1.

2.5.5 From the main steering position the field of vision is to extend over an arc from dead ahead to at least 60° on each side. *See* Fig. 4.2.2.

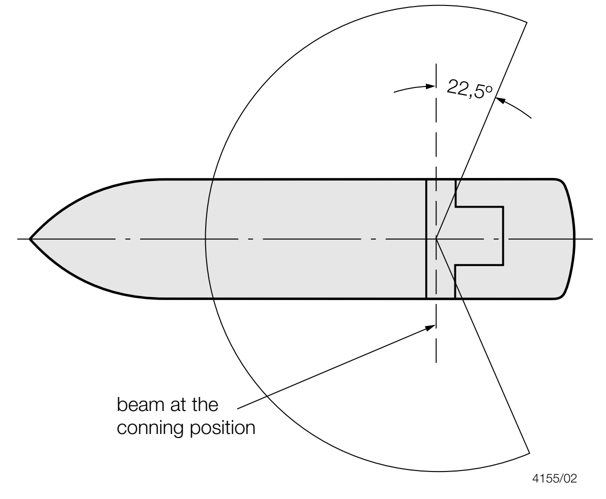


Fig. 4.2.1

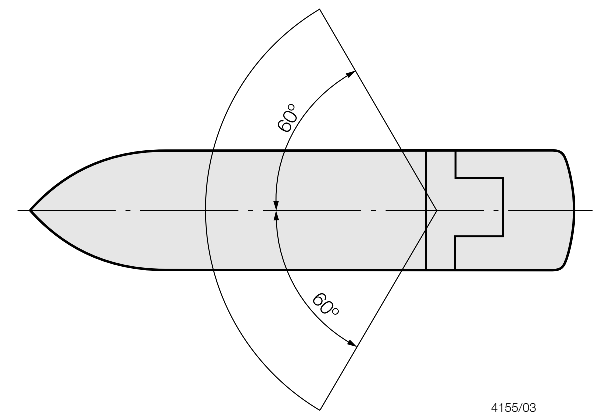


Fig. 4.2.2

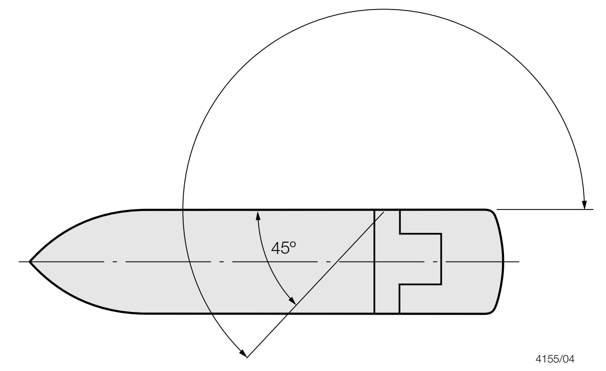


Fig. 4.2.3

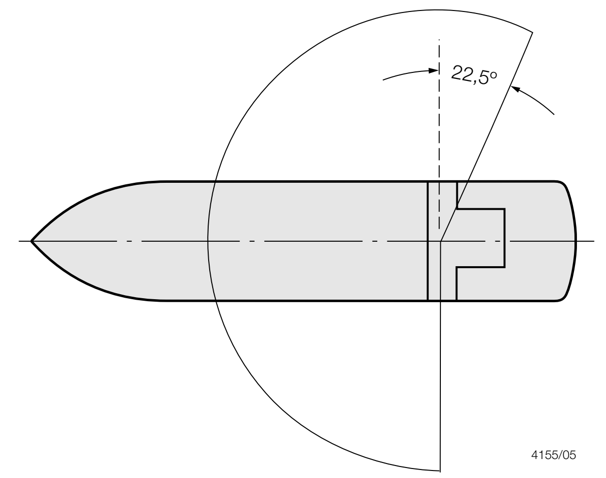


Fig. 4.2.4

2.5.6 From each bridge wing the field of vision is to extend over an arc from at least 45° on the opposite bow through dead ahead and then aft to 180° from dead ahead. *See* Fig. 4.2.3.

2.5.7 There is to be a line of sight from the port wing to the starboard wing through the wheelhouse.

2.5.8 The ship's side is to be visible from the bridge wing.

2.5.9 From workstations for functions other than navigation the field of vision is to enable an effective lookout to be maintained and in this respect is to extend at least over an arc from 90° on the port bow, through forward, to 22,5° abaft the beam on the starboard side. *See* Fig. 4.2.4.

2.5.10 The height of consoles is not to interfere with the fields of vision defined above and is not to exceed 1350 mm.

■ *Section 3* **Workstations**

3.1 Navigation workstation

3.1.1 A workstation for navigation is to be arranged to enable efficient operation by one person under normal operating conditions. The workstation area is to be sufficient to allow at least two operators to use the equipment simultaneously.

3.1.2 An adequate conning position is to be provided close to the forward centre window. If the view in the centre-line is obstructed by large masts, equipment, etc., two conning positions giving a clear view ahead are to be provided, one on the port side and one on the starboard side of the centreline, no more than 5 m apart.

3.1.3 The main steering position is to be located on the ship's centreline unless the view ahead is obstructed by large masts, equipment, etc. In this case the steering position is to be located a distance to starboard of the centreline sufficient to obtain a clear view ahead and special steering references for use by day and night are to be provided, e.g. sighting marks forward.

3.1.4 The following facilities are to be provided at the navigation workstation:

- Radar and radar plotting facilities, (*see* 3.1.5);
- position fixing system displays (*see* 3.1.6);
- echo sounder display;
- speed and distance indications, *see* 3.1.10 and 3.1.11;
- gyro compass display (*see* 3.1.7);
- magnetic compass display;
- wind speed and direction indication;
- steering controls and indication (*see* Vol 2, Pt 6, Ch 1,7);
- rate of turn indication;
- course/track controls and indications, (*see* 3.1.8 and 3.1.9);
- main propulsion and thruster controls and indication (*see* Vol 2, Pt 9, Ch 1,2.6);
- watch safety system acknowledge;
- watch safety system manual initiation;
- internal communications system;
- VHF radiotelephone;
- time indication;
- window clear view controls;
- navigation lights controls;
- whistle control;
- morse light keys;
- wheelhouse/equipment lighting controls.
- automatic ship identification system (AIS) information.

3.1.5 Two functionally independent radars or alternative means are to be provided to determine and display the range and bearing of radar transponders and other surface craft, obstructions, buoys, shorelines and navigational marks. One of the radars is to operate in the X-band (9 GHz) and the other is to operate in the S-band (3 GHz). Both radars are to include automatic plotting aids to determine collision risks, and at least one radar is to be equipped with an automatic radar plotting aid (ARPA), capable of tracking at least 20 targets, while the other is to be either ARPA or an automatic tracking aid (ATA).

3.1.6 At least two different automatic position fixing systems giving a continuous display of latitude and longitude are to be provided. One of these is to be GPS or equivalent, the other is to be Decca and/or Loran C depending on the area of operation.

3.1.7 A gyrocompass or alternative means for determining, displaying and transmitting the ships heading is to be provided. The heading information is to be used directly by the radars, radar plotting aids and automatic identification system, *see* 3.1.5 and 3.1.12. The gyrocompass is to be provided with a gyrocompass heading repeater located at the emergency steering position in the steering gear compartment and a gyrocompass bearing repeater allowing bearings to be taken over 360°.

3.1.8 An autopilot, track control system or alternative means of automatically maintaining the ships heading or a straight track is to be provided. At any time, it is to be possible to immediately restore manual control. The arrangements for restoring manual control are to be such that inadvertent operation is prevented.

3.1.9 Where automatic track following is provided sufficient warning is to be given of the approach of a waypoint, so that, in the event of no acknowledgement from the officer of the watch, there is adequate time for the back-up navigator to reach the bridge and accept the change of course.

3.1.10 A speed log or alternative means of indicating the ships speed and distance through water is to be provided. The speed through water measurement is to be used directly by the ARPA as an aid to collision avoidance.

3.1.11 A speed log or alternative means of indicating the ships speed and distance over ground is to be provided. Speed over ground is to be indicated in both the fore-aft and athwarships directions.

3.1.12 Navigational systems and equipment are to be of a type approved by the naval authority and in conformity with appropriate performance standards not inferior to those adopted by IMO from time to time. Documentary evidence to this effect is to be submitted.

3.1.13 Where alternative means of fulfilling the navigational requirements are permitted, the means are to be approved by the Naval Authority and in conformity with appropriate performance standards.

3.1.14 Electrical and electronic equipment shall be installed in so that electromagnetic interference does not affect the proper function of the navigational systems and equipment. The installation should comply with IEC 60533 Electrical and electronic installations in ships – Electromagnetic compatibility or an acceptable equivalent standard.

3.2 Voyage planning workstation

3.2.1 A voyage planning workstation is to be provided at which the following facilities are available:

- chart table with instruments;
- position fixing systems;
- time indication.

3.2.2 Time indication at the voyage planning workstation is to be derived from the same system as used at the navigation workstation.

3.2.3 The chart table is to be large enough to accommodate all chart sizes normally used internationally for maritime traffic and is to have facilities for illuminating the chart. *See also* 2.3.8.

Section 4 Systems

4.1 Alarm and warning systems

4.1.1 Alarms associated with navigation equipment are to be both audible and visual and are to be centralized for efficient identification. Repeater displays may be fitted on the bridge wings and at other appropriate positions on the bridge where necessary.

4.1.2 The following alarms are to be provided:

- closest point of approach;
- shallow depth;
- waypoint approaching (where automatic track following is provided);
- off-course;
- off-track (where automatic track following is provided);
- steering alarms (*see* Table 1.8.1 in Vol 2, Pt 6, Ch 1 or Table 2.6.1 in Vol 2, Pt 4, Ch 3 as applicable);
- navigation light failure;
- gyro compass failure;
- watch safety system (where provided) failure;
- failure of any power supply to the distribution panels referred to in 4.4.1.

4.1.3 Audible signals are to be designed not to startle operators. Suitable types are shown in Table 4.4.1.

Table 4.4.1 Suitable audible signals

Type	Typical characteristics	Considerations
Buzzer	Low intensity and frequencies	Good alerting in quiet environment without startling
Bell	Moderate intensity and frequencies	Penetrates low frequency noise well, abrupt onset has a high alert value
Chime	Moderate intensity and frequencies	Good in quiet environment, non startling
Tone	Moderate intensity and limited frequency range	Convenient for intercom transmission, high alert value if intermittent

4.2 Watch safety system

4.2.1 A watch safety system to monitor the well-being and awareness of the watchkeeper is to be provided. The system is not to cause undue interference with the performance of bridge functions.

4.2.2 The system is to be such that at a predetermined time the watchkeeper receives warning that he must indicate his well-being by accepting the warning.

4.2.3 The time interval between warnings is to be adjustable up to a maximum of 12 minutes.

4.2.4 It is to be possible to acknowledge the warning at the navigation workstation and at other appropriate locations on the bridge where an effective look-out may be kept. Acknowledgement of any alarm is automatically to reset the time interval between warnings. Manual adjustment of controls may also be used for this purpose.

4.2.5 In the event that the watchkeeper fails to respond and accept the warning or if any alarm has not been acknowledged on the bridge within a period of 30 seconds, the system is to immediately initiate a watch alarm to warn the Commanding Officer and the appointed back-up navigator through a fixed installation. Manual initiation of the watch alarm from the bridge is to be possible at any time.

4.2.6 The system is to be designed and arranged such that only the ship's Commanding Officer has access for enabling and disabling it and setting the appropriate intervals, and such that it cannot be operated in an unauthorized manner, e.g. removing the fuses or keeping the acknowledgement button permanently depressed.

4.2.7 The fixed installation is to be connected to the Commanding Officer's and Navigating Officers' cabins, offices, mess and public rooms.

4.2.8 Acknowledgement of the watch alarm is only to be possible on the bridge.

4.2.9 If, depending upon the shipboard work organization, the back-up navigator may attend locations not connected to the alarm transfer system, a wireless portable device is to be provided enabling both the transfer of alarms and two way speech communication with the bridge. An audible warning from the portable device is to be provided in the event of loss of the wireless link with the bridge. Alternative arrangements will be considered.

4.3 Telephone system

4.3.1 A telephone system is to be provided to enable two way speech communication between the wheelhouse and at least the following locations:

- machinery control station space; *see* Vol 2, Pt 9, Ch 1,2.6.8;
- emergency steering position in the steering gear compartment;
- Commanding Officer's and Navigating Officers' cabins, offices, mess and public rooms.

4.3.2 The bridge is to have priority over the system.

4.3.3 A list of extension numbers is to be clearly displayed adjacent to each telephone.

4.4 Power supplies

4.4.1 Local distribution panels are to be provided for all items of electrically operated navigational equipment, the telephone system, the watch safety system and the clear view systems. These panels are to be supplied by two exclusive circuits, one fed from the main source of electrical power and one fed from an emergency source of electrical power. Each item of equipment is to be individually connected to its distribution panel. The power supplies to the distribution panels are to be arranged with automatic changeover facilities between the two sources. Failure of any power supply to the distribution panels is to initiate an audible and visual alarm. This alarm should be included in the ship's alarm system as required by Vol 2, Pt 9, Ch 1,3.2, where applicable.

4.4.2 The watch safety system and the telephone system are to remain operational during blackout conditions.

4.4.3 Following a loss of power which has lasted for 45 seconds or less, all navigation functions are to be readily re-instated. In this respect, all navigational equipment is to recover within five minutes, with minimum operator intervention, by virtue of the emergency source and, where necessary, an uninterruptible power source.

■ *Section 5*
Integrated Bridge Navigation Systems – IBS notation

5.1 General

5.1.1 Where it is proposed that the bridge navigation functions are so arranged as to form an integrated bridge system the requirements of 5.2 to 5.6 are to be complied with.

5.2 General requirements

5.2.1 For assignment of the notation **IBS**, the ship is also to be assigned either **NAV** or **NAV1**.

5.2.2 The design features for computer hardware, local area networks and software required by Vol 2, Pt 9, Ch 1,2.9, 2.10, and 2.11 respectively are to be complied with. Alarms associated with hardware and data communication are to be incorporated in the centralized alarm system required by 4.1.

5.2.3 Failure of a part of the integrated bridge navigation system is not to affect other parts except for those that directly depend upon the information from the defective part. Following such a failure, it is to be possible to operate each other part of the system separately.

5.3 Equipment

5.3.1 Two independent gyro compasses are to be available to provide heading information to the system. The heading signal from each gyro compass is to be continuously available for display and for providing input to all relevant items of navigational equipment.

5.3.2 Only one gyro compass is to be used by the integrated bridge system at any time for main display and control purposes. The navigating officer is to be able to switch between compasses at any time and the non-selected compass is to be used automatically as the independent heading source for the off-course warning required by 3.1.8.

5.3.3 It is to be possible to compare readings from each gyro compass via the navigation workstation displays.

5.3.4 Automatic comparison between the gyrocompasses is to be provided and an alarm given if the difference between heading signals exceeds a pre-set value.

5.3.5 The capability to receive and utilise differential GPS corrections (or an equivalent) is to be included in the integrated bridge system.

5.3.6 As a minimum, the following information is to be displayed at the navigation workstation via visual display units:

- steering mode;
- gyro heading;
- course to steer;
- rate of turn;
- rate of turn order;
- speed and distance (from log and from GPS);
- speed order;
- waypoint bearing, distance and ETA;
- water depth and alarm setpoint;
- position fix from each available system;
- main propulsion and thruster indication (*see* Vol 2, Pt 9, Ch 1,2.6);
- steering indication (*see* Vol 2, Pt 6, Ch 1,7);
- wind speed and direction;
- time (*see* 3.2.2).

5.3.7 Additional information such as machinery monitoring, fire detection, etc., may also be provided via additional pages on the visual display units.

5.3.8 The centralized alarm system and the watch safety system required by 4.1 and 4.2 respectively are to be incorporated as functions of the integrated bridge system and are to be presented to the navigating officer via the conning display.

5.3.9 A route planning capability is to be provided by the integrated bridge system. This is to allow a voyage to be pre-planned as a series of waypoints and turn radii. It is to be possible to edit a voyage plan at any time without affecting route control and monitoring.

5.3.10 An automatic track following capability is to be provided in conjunction with the pre-planned route. The position fix used by the system is to be based at least upon GPS or equivalent, and is to be cross-checked by dead-reckoning based upon speed over ground provided by the ship's log. In areas where differential corrections are available it is to be possible to utilize these in the track following system.

5.3.11 In the event of failure of the track following capability, the current heading or rate of turn is to be maintained until manually altered by the navigating officer or officer in charge of the watch. The quality of position fix input to the system is to be monitored (*see also* 3.1.9 and 4.1.2).

5.3.12 The integrated bridge system is to incorporate an electronic chart display which combines simultaneously a high resolution colour representation of a nautical chart with a continuously updated record of own ship's position, pre-planned track, and radar targets in the vicinity. The entire tactical situation is to be displayed for the navigating officer in such a way that any risk from approaching, overtaking or crossing vessels may be assessed. Factors affecting the vessel's freedom to manoeuvre, such as water depths, channel boundaries, separation zones and other traffic are to be shown on the display.

5.3.13 The following alarms are to be provided and included in the centralized alarm system specified by 4.1.1:
- off-track (*see* 3.1.8);
- waypoint approaching (*see* 3.1.9);
- position fix inaccurate/lost;
- loss of heading input;
- loss of log input;
- equipment or sub-system failure;
- gyro mis-match.

5.3.14 Manual adjustment of any of the facilities of the integrated bridge system is to reset automatically the watch safety interval timer.

5.4 Navigation workstation

5.4.1 Integrated display and control functions are to adopt a consistent man-machine interface philosophy and strategy. Particular consideration is to be paid to symbols, colours, controls, and information priorities.

5.4.2 The size, colour and density of text and graphic information displayed on a visual display unit is to be such that it may be read easily from the normal operator position under all operational lighting conditions.

5.4.3 Means are to be provided for the manual adjustment of the brightness of each visual display unit.

5.4.4 All information is to be presented on a background of high contrast, emitting as little light as possible by night.

5.4.5 Paged displays are to be presented in a way which allows the operator to find quickly the information needed. An overview page is to be easily available to remind the operator of the paging system.

5.4.6 Pages are to have a standardized format. Particular types of information and functional areas should be presented in a consistent manner, e.g. in the same position on different pages.

5.4.7 Each page is to have a unique identifying label on the screen.

5.4.8 Keyboards are to be divided logically into areas enabling rapid access to a desired function. Alphanumeric, paging and specific system keys are to be grouped separately and grouping is to be identical at all operator interfaces.

5.4.9 Soft keys may be used for display control and operation of systems non-critical to the safe operation of the vessel, otherwise dedicated controls are to be used.

5.4.10 Functions requested by the operator are to be acknowledged and confirmed by the system on completion.

5.4.11 Default values, where applicable, are to be indicated by the system when requesting operator input.

5.4.12 If an input error is detected by the system it is to allow the operator to correct the error immediately.

5.4.13 The system is to require confirmation from the operator for critical actions, e.g., they should not rely on single keystrokes.

5.4.14 Input error messages are to guide the correct responses, e.g.:

use Invalid entry: re-enter set point between 0 and 10

not Invalid entry.

5.4.15 All functions of the integrated bridge system are to remain available in the event of a single failure of an operator interface. This is to be achieved through redundancy in the integrated bridge system interfaces.

5.5 Alarm management

5.5.1 All alarms provided on the bridge are to be included in the centralized alarm system required by 4.1.1.

5.5.2 In general the alarm system is to be in accordance with Vol 2, Pt 9, Ch 1,2.3.

5.5.3 Alarm management on priority and functional levels is to be provided within the integrated bridge system, including distribution and recording of alarms, as required. Priorities are to be as follows:

(a) **Emergency alarms** – alarms which indicate that immediate danger to human life, or to the ship and its machinery exists and that immediate action must be taken.

(b) **Distress, urgency and safety alarms** – alarms which indicate that a caller is in distress or has an urgent message to transmit.

(c) **Primary alarms** – alarms which indicate a condition that requires prompt attention to prevent an emergency condition.
(d) **Secondary alarms** – all other alarms.

5.5.4 Appropriate alarm management on general and functional levels is to be provided. This includes prioritization, distribution and recording of alarms as required.

5.5.5 Within each priority, alarms are to be arranged in groups in order to reduce the quantity of information presented to the operator. More detailed information on the group alarm is to be readily available from the integrated bridge system on request.

5.5.6 The following alarms are not to be grouped:

- emergency alarms;
- alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery;
- steering gear alarms.

5.5.7 Alarms are to be displayed in order of priority. Within the priorities alarms are to be displayed in the order in which they occur. The visual display units are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

5.5.8 Unacknowledged alarms are to be distinguished by either flashing text or a flashing marker adjacent to the text, and not merely by a change of colour. Acknowledged alarms are to be distinguished by either steady illuminated text or a steady illuminated marker adjacent to the text.

5.6 Power supplies

5.6.1 All equipment forming part of the integrated bridge navigation system is to be regarded as navigational equipment and as such is to have power supplies in accordance with 4.4.

■ *Section 6* Trials

6.1 General

6.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, tests are to be carried out to ensure satisfactory operation of the navigational equipment. These tests are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are based on the approved test schedule as required by 1.2.1.

6.1.2 Three copies of the test schedule, signed by the Naval Authority, Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the others submitted to LR and the Naval Authority.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for ships having machinery redundancy, and are in addition to the relevant requirements of the *Rules and Regulations for the Classification of Naval Ships* contained in Volumes 1 and 2.

1.1.2 The requirements, which are optional, cover machinery arrangements and control systems necessary for ships which have propulsion and steering systems configured such that, in the event of a single failure in equipment, the ship will retain in operation not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability at a service speed of not less than seven knots. The requirements also cover machinery arrangements where the propulsion and steering systems are installed in separate compartments such that, in the event of a loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

1.1.3 Requirements additional to these Rules may be imposed by the Naval Authority.

1.1.4 Sections 2, 3 and 4 state the applicable requirements for arrangements necessary to maintain availability of propulsion and manoeuvring capability, in the event of a single failure in equipment. Ships complying with the applicable requirements of Sections 2 to 4 of this Chapter will be eligible for the machinery class notation **PMR** (Propulsion Machinery Redundancy), **SMR** (Steering Machinery Redundancy) or **PSMR** (Propulsion and Steering Machinery Redundancy).

1.1.5 Section 5 states the additional requirements necessary to maintain availability of propulsion and manoeuvring capability where machinery is installed in separate compartments and the loss of any one compartment due to fire or flooding has been addressed. Ships complying with the applicable requirements of Sections 2 to 5 of this Chapter will be eligible for the machinery class notation **PMR★** (Propulsion Machinery Redundancy in separate machinery spaces), **SMR★** (Steering Machinery Redundancy in separate machinery spaces) or **PSMR★** (Propulsion and Steering Machinery Redundancy in separate machinery spaces).

1.2 Plans and information

1.2.1 In addition to the plans and information required by this Part and Volume 2, Part 6, the information detailed in 1.2.2 to 1.2.6 is also to be submitted.

1.2.2 **Machinery spaces**. Plans showing the general arrangement of the machinery spaces, together with a description of the propulsion system, main and emergency electrical power supply systems and steering arrangements are to be submitted. The plans are to indicate segregation and access arrangements for machinery spaces and associated control rooms/stations.

1.2.3 **Failure Mode and Effects Analysis (FMEA)**. For the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements, a FMEA report is to be submitted and is to address the requirements identified in Sections 2 and 5.

1.2.4 **Manoeuvring capability**. An assessment of the ship's ahead and astern manoeuvring capability, under the following operating conditions, is to be submitted:

(a) Where only 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems is available.

(b) Where the steering capability requirements described in 3.2.1 are available.

See IMO Resolution A.751(18) *Interim Standards for Ship Manoeuvrability* provides guidance on standard manoeuvres required in an assessment of the manoeuvrability of ships.

1.2.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that the ship is capable of being operated with machinery functioning as described in Section 3 is to be submitted. In addition, any testing programme that may be necessary to prove the conclusions of the FMEA is to be submitted.

1.2.6 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars of machinery and control systems.

(b) General description of systems for propulsion and steering.

(c) Operating instructions for all machinery and control systems used for propulsion and steering.

(d) Procedures for dealing with the situations identified in the FMEA report.

■ *Section 2*
Failure Mode and Effects Analysis (FMEA)

2.1 General

2.1.1 A FMEA is to be carried out in accordance with 2.1.2 to 2.1.7, for the propulsion systems, electrical power supply systems and steering systems to demonstrate that a single failure in equipment or loss of an associated sub-system will not cause loss of all propulsion and/or steering capability as required by a class notation. Typical sub-systems include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

2.1.2 The FMEA is to be carried out using the format presented in Table 5.2.1 or an equivalent format that addresses the same safety issues. Analyses in accordance with IEC 600812, *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or IMO MSC Resolution 36(63) Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.1.3 The FMEA is to be organized in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

2.1.4 The FMEA is to:
(a) identify the equipment or sub-system, mode of operation and the equipment;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode; and
(e) identify trials and testing necessary to prove conclusions.

2.1.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, their failure need only be dealt with as a cause of failure of the pump.

2.1.6 Where FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

2.1.7 The FMEA is to establish that in the event of a single component failure:
(a) For **PSMR** and **PSMR★** notations, that not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems is available, and that steering capability is retained at a speed of seven knots.
(b) For **PMR** and **PMR★** notations, that not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems remain available.
(c) For **SMR** and **SMR★** notations, steering capability at a speed of seven knots is to be retained.

Table 5.2.1 Failure Mode and Effects Analysis

System				Element							
Item No.	Component description	Function	Mode of operation	Failure mode	Failure cause	Failure detection	Effect of failure		Severity	Corrective action	Remarks
							On item	On system			

NOTE
The severity category is to be in accordance with the following:
(a) Catastrophic; (b) Hazardous; (c) Major or (d) Minor.

Section 3 Machinery arrangements

3.1 Main propulsion machinery

3.1.1 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, independent main propulsion systems are to be provided so that at least 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems will continue to be available in the event of a single failure of a system or item of equipment. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a manoeuvring speed and, for **PSMR** and **PSMR★** notations, give adequate manoeuvring capability, *see* 1.2.4.

3.2 Steering machinery

3.2.1 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, independent steering systems for manoeuvring the ship are to be installed, such that steering capability will continue to be available in the event of any of the following:
(a) Single failure in the steering gear equipment.
(b) Loss of power supply or control system to any steering system.

3.3 Electrical power supply

3.3.1 The main busbars of the switchboard supplying the propulsion machinery and essential services are to be capable of being isolated by a multi-pole linked circuit breaker, disconnector, or switch-disconnector into at least two independent sections.

3.3.2 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply essential services such that at least 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems will continue to be available where **PSMR**, **PSMR★**, **PMR** and **PMR★** notations are required. *See* 3.2.1 for steering machinery requirements.

3.3.3 For ships capable of operating with one service generator connected to the switchboard, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on loss of the service generator. Sequential starting of essential services is to be provided.

3.3.4 For ships operating with two or more generator sets in service connected to the switchboard, arrangements are to be such that, in the event of loss of one generator, the remaining set(s) is to be adequate for the continuity of essential services supplied from that switchboard. This may be achieved by preferential tripping of non-essential services. Alternatively, arrangements can be such that a standby generator will start automatically and connect to the switchboard on loss of one of the generator sets in service.

3.4 Essential services for machinery

3.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so that 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and steering capability are maintained in the event of a single failure in any of the services, where required by the respective class notations.

3.5 Oil fuel storage and transfer systems

3.5.1 The arrangements for the storage of oil fuel bunkers are to ensure that there is an adequate supply of existing oil fuel on board to allow sufficient time for a shore-based quality analysis of new bunkers, in accordance with ISO 8217 *Petroleum Products – Fuels (Class F) Specification of Marine Fuels* prior to use.

3.5.2 Provision is to be made to enable samples of oil fuel to be taken at the bunkering manifolds.

Section 4 Control arrangements

4.1 General

4.1.1 This Section states the requirements for the installation of control, alarm and safety systems but does not signify that machinery spaces may be operated unattended. For unattended machinery space operation, compliance with Vol 2, Pt 9, Ch 1,3 is also required.

4.1.2 The control, alarm and safety systems required in 4.2 are to comply with Vol 2, Pt 9, Ch 1,2.

4.2 Bridge control

4.2.1 The controls, alarms, instrumentation and safeguards required in 4.2.2 to 4.2.6 are to be provided on the bridge.

4.2.2 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, means are to be provided to ensure satisfactory control of propulsion in both the ahead and astern directions when all main propulsion systems are functioning and when one propulsion system is not available.

4.2.3 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, means are to be provided to ensure satisfactory control of steering when all steering systems are functioning and when any one steering system is not available.

4.2.4 Where required by 5.4.3, isolation of essential services is to be carried out either automatically or manually from the bridge. Indication of the status of isolation arrangements is to be provided on the machinery console.

4.2.5 A means of indicating the operational status of running and standby machinery is to be provided for the propulsion systems, the supply of electrical power, steering systems and other essential services.

4.2.6 Alarms are to be provided in the event of:
(a) A fire in any machinery compartment.
(b) A high bilge level in any machinery compartment. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping bilges, if applicable, are to comply with Vol 2, Pt 9, Ch 1,3.6.

■ *Section 5* Separate machinery spaces ★ (star) Enhancement

5.1 General

5.1.1 This Section states the additional requirements where propulsion and steering machinery are installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

5.1.2 The machinery arrangements, control arrangements and FMEA required by Sections 2 to 4, together with testing and trials requirements in Section 6, are to be complied with in addition to 5.2 to 5.7.

5.2 Machinery arrangements

5.2.1 The main propulsion machinery is to be arranged in not less than two compartments such that, in the event of the loss of one compartment, propulsion power and/or manoeuvring capability will continue to be available, where required by the respective class notations.

5.2.2 The steering systems are to be arranged in not less than two separate compartments, such that steering capability will continue to be available in the event of the loss of one compartment, where required by the respective class notations.

5.3 Electrical power supply

5.3.1 The generating sets and converting sets required by 3.3.1 are to be arranged so that they are located in at least two separate machinery compartments.

5.3.2 The independent sections of the switchboard required by 3.3.1 are to be arranged in not less than two separate compartments.

5.3.3 In the event of the loss of one compartment, there is to be continuity of sufficient electrical power to supply essential services, such that propulsion power and steering capability will continue to be available.

5.4 Essential services for machinery

5.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged, so that propulsion power and steering capability are maintained in the event of the loss of one machinery compartment.

5.4.2 The design of systems which may have a common source, such as those used for supplying oil fuel, lubricating oil, fresh and sea-water cooling, ventilation of compartments and engine starting energy, is to ensure continuous availability of supply in the event of the loss of any one compartment. Where applicable, continuous availability of heating services, oil fuel and water treatments is also to be provided. *See* 3.5 and 5.6 for oil fuel storage and transfer systems.

5.4.3 Where essential services are arranged so that they may supply machinery in another compartment, means of isolation from that compartment is to be provided.

5.4.4 Where pumps for essential services are arranged to supply more than one compartment, standby pumps for the same supplies are to be provided in a different compartment. The standby pumps are to be arranged to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

5.5 Bilge drainage arrangements

5.5.1 The drainage arrangements for any machinery space are to be provided with means of isolation from other compartments.

5.6 Oil fuel storage

5.6.1 The oil fuel service tanks required by Vol 2, Pt 7, Ch 3,4.17.2 are to be located in separate compartments.

5.6.2 Provision is to be made to ensure that oil fuel preparation and transfer arrangements to the oil fuel service tanks are continuously available in the event of the loss of any one compartment, *see also* 5.4.2.

5.7 FMEA

5.7.1 The FMEA required by 2.1.1 for the propulsion systems, electrical power supplies, essential services, control systems and steering arrangements is also to address the following:
(a) Fire in a machinery space or control room.
(b) Flooding of any watertight compartment which could affect propulsion or steering capability.
(c) Separation of machinery spaces.

■ *Section 6*
Testing and trials

6.1 Sea trials

6.1.1 In addition to the requirements for sea trials in Vol 2, Pt 1, Ch 2,16.1, trials are to be carried out to demonstrate that when the ship is operating with 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems, a manoeuvring speed can be maintained with adequate steering capability, where required by the respective class notations.

6.1.2 Trials are to be carried out to demonstrate the ship's steering capability in accordance with the assessment required by 1.2.4 with one steering system out of action.

6.1.3 Where the FMEA report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of essential systems.

6.1.4 During sea trials, the operational envelope(s) is to be determined under conditions detailed in 3.1 or 3.2 as required for the class notation.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements contained in these Rules apply to naval ships of all rudder and propulsion types, where the length between perpendiculars, L_{pp}, is 50 m and over.

1.1.2 These requirements, which are optional, establish a ship's manoeuvring capability by assessing its characteristics in conjunction with engine and propulsion performance. Such requirements are additional to those applicable in the *Rules and Regulations for the Classification of Naval Ships* contained in Volumes 1 and 2, hereinafter referred to as the Rules for Naval Ships.

1.1.3 Where a ship's manoeuvring capability is assessed and verified in accordance with these Rules, it will be eligible for the class notation specified in 1.2.

1.1.4 For a ship under construction, the requirements of Sections 2 and 3 are to be met.

1.1.5 For an existing ship, all available data and full-scale manoeuvring information are to be submitted. This information will be examined against the requirements of these Rules and, if acceptable, the scope of the representative manoeuvres required in Section 3 may be reduced.

1.1.6 These Rules satisfy the requirements of IMO Resolutions A.601(15), *Provision and Display of Manoeuvring Information On Board Ships* and A.751(18), *Interim Standards for Ship Manoeuvrability*.

1.1.7 Requirements additional to those in this chapter may be imposed by the Naval Authority.

1.2 Class notations

1.2.1 In addition to the hull and machinery class notations defined in Vol 1, Pt 1, Ch 2,3, ships complying with these requirements will be eligible to be assigned the Lloyd's Manoeuvring Assessment notation **LMA**.

1.2.2 Details of any subsequent modifications to the ship's structure or equipment resulting in any alteration to the data specified in 1.3 are to be submitted for re-assessment of the ship's manoeuvring capability.

1.3 Information and plans to be submitted

1.3.1 Information, as specified in 1.3.2, is to be submitted for the ship in the condition to be used during verification trials.

1.3.2 Information required for assessment:

(a) Ship data, where applicable, *see* Vol 1, Pt 3, Ch 1,5 of the Rules for Naval Ships:
- Length overall.
- Length between perpendiculars (L_{pp}).
- Moulded breadth.
- Draught at forward perpendicular.
- Draught at after perpendicular.
- Block coefficient.
- Waterplane area coefficient.
- Distance of LCG from amidships (positive fwd).
- Height of VCG above baseline.
- Cross-sectional area of bulbous bow, if applicable, at the forward perpendicular below the load waterline.
- Wetted area of appendages, excluding rudder and propeller.
- Transverse metacentric height above baseline.
- Extreme height of the ship structure above baseline.

(b) Propeller data:
- Number of propellers and direction of rotation.
- Athwartship position of propellers.
- Height from baseline, to propeller axis.
- Longitudinal distance of propeller disc from amidships.
- Type of propellers (e.g. fixed or controllable pitch, ducted).
- If ducted, type of duct (e.g. accelerating/decelerating) and designation (e.g. NSMB 19A/37 or special type).
- Propeller diameter.
- Mean pitch for fixed pitch propellers.
- Design pitch and range of pitch for controllable pitch propellers.
- Number of blades.
- Developed blade area ratio.

(c) Rudder data:
- Number of rudders and type.
- If active type, rudder characteristics (e.g. rotating cylinder, variable fin, flap length, tail angle).
- Lateral underwater projected area of both rudder and horn, where applicable, *see* shaded area in Fig. 6.1.1.
- Mean height of rudder, H_R, *see* Fig. 6.1.1.
- Longitudinal distance of rudder's leading edge from amidships.
- Maximum rudder angle.
- Minimum time taken to put rudder over from 35 degrees on either side to 30° on the other side, *see* Vol 2, Pt 6, Ch 1.

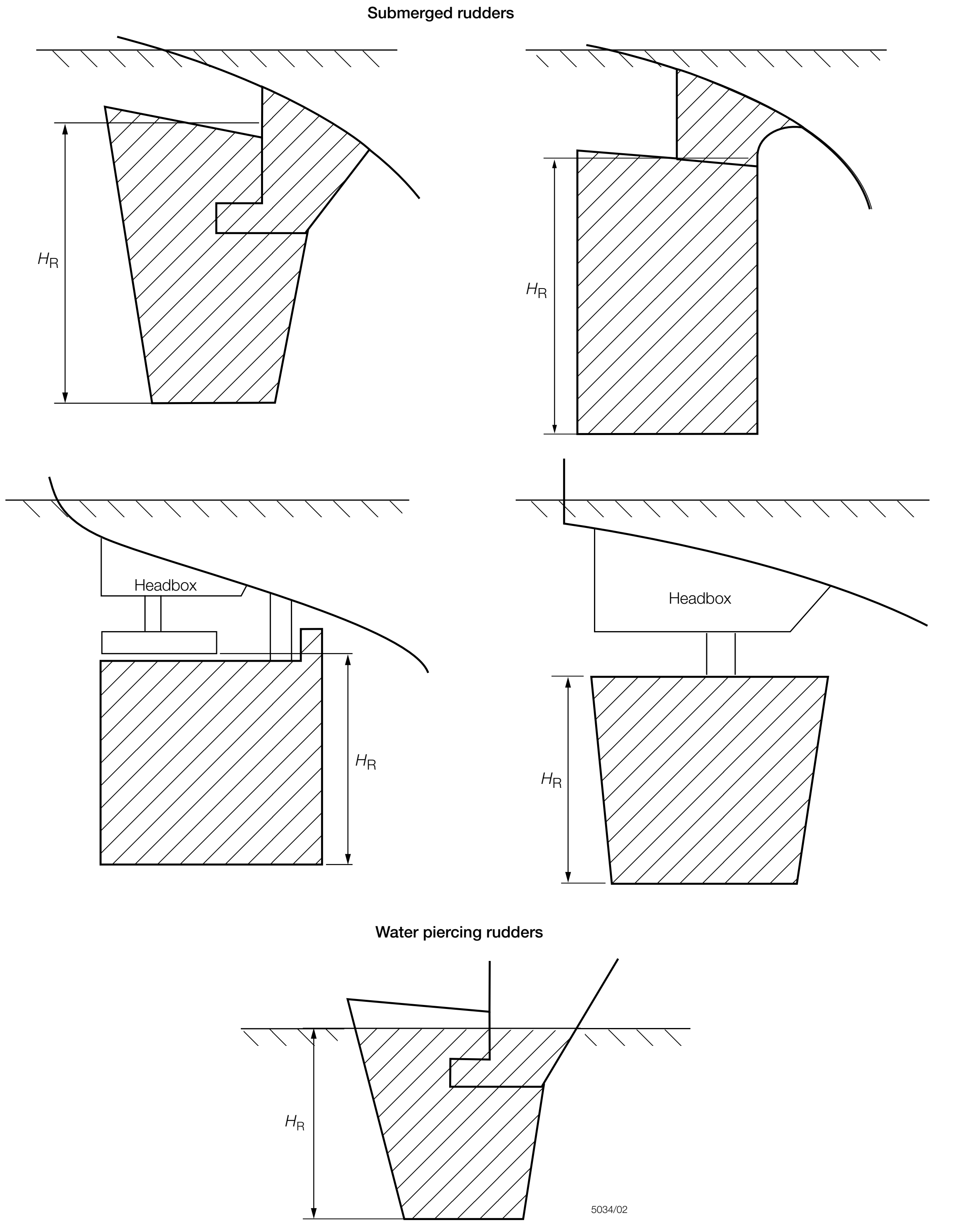


Fig. 6.1.1 Mean height of rudder, H_R

(d) Propulsion data:
- Propulsion type (e.g. gas turbine, electric, steam, diesel).
- Steady-state developed shaft torque or ship's speed versus propeller RPM/pitch at each telegraph or combinator setting as identified on the bridge. Times for effecting changes in engine telegraph settings for both normal and emergency conditions.
- Critical or barred RPM ranges.
- Main engine stalling revs, if applicable.

(e) Transverse thruster data, if applicable:
- Type of thruster (e.g. tunnel, Gill).
- Longitudinal distance of thruster axis from amidships.
- Thruster propeller characteristics, viz: number of blades, diameter and pitch.
- Power at MCR.
- Time delay to achieve full thruster RPM.
- Time delay to achieve full reverse RPM/pitch.
- Predicted thrust versus RPM/pitch curve in clear deep water.
- Thruster tunnel diameter and height of its centre above the keel.
- Details of hull profile in the vicinity of thruster tunnel.

(f) Side fins, *see* Fig. 6.1.2:
- Lateral fin area, *see* shaded area in Fig. 6.1.2.
- Height of fin, H_F.
- Longitudinal position of the fin, X_F, from amidships (positive fwd).
- Lateral position of the fin, Y_F, from the centreline.

(g) Wind parameters:
- Lateral projected area above waterline.
- Transverse projected area above waterline.
- Lateral projected area of the superstructure.
- Sum of the lengths forming the perimeter of the lateral projection of the ship, excluding waterline.
- Distance from the FP to the centroid of the lateral projected area.

(h) Ship performance data:
- Ship design speed.
- Propeller RPM at ship design speed.
- Power and percentage MCR to which ship speed and RPM apply.
- Draught conditions applicable to powering condition.
- Sea-state applicable to powering condition.
- RPM margin on propeller in the case of a new ship.

(j) Plans:
- A general arrangement plan of the ship.
- A lines plan.
- Forward and after bridge blind zones with dimensions specified.

(k) Manoeuvring information:
- Wheelhouse poster and manoeuvring booklet, *see* 2.5.

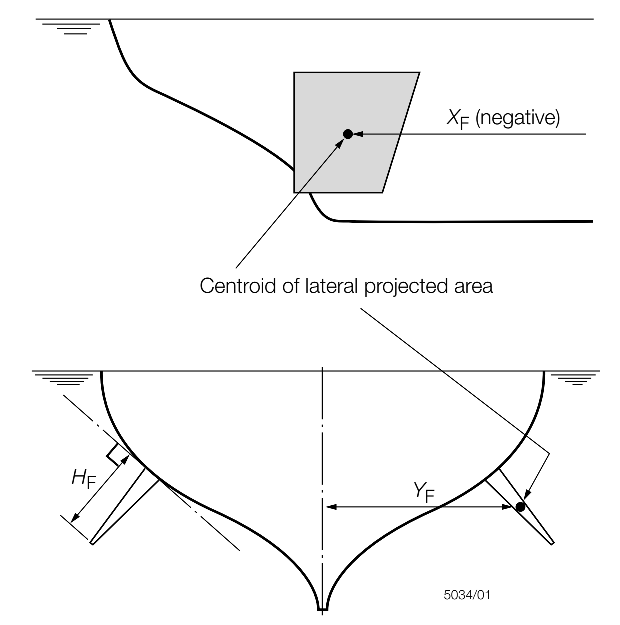


Fig. 6.1.2 Side fin dimensions

1.4 Sister ships

1.4.1 In so far as these Rules are concerned, a ship will be deemed a sister ship, if that ship has been built to the same plans as the lead ship which has completed a manoeuvring assessment in accordance with those requirements specified in 1.1.4 or 1.1.5.

1.4.2 In demonstrating that a ship is a sister ship, the hull dimensions, weights, tank capacities and arrangements, engine power and propulsion, rudder, performance and general superstructure design are to be identical.

1.4.3 The manoeuvring information for the lead ship may be used for the sister ship. All duplicate data is to be marked, 'Data duplicated from sister ship (name of lead ship)'.

1.4.4 A sister ship will be required to carry out the following representative manoeuvres, in accordance with 3.1.2:

(a) A ship's stopping manoeuvre from full sea speed achieved by the application of full astern thrust.
(b) A 10°/10° zig-zag manoeuvre under the approach conditions defined in 3.4.
(c) A 20°/20° zig-zag manoeuvre under the approach conditions defined in 3.4.
(d) An initial turning trial under the approach conditions defined in 3.4.

Section 2 Assessment for LMA notation

2.1 General

2.1.1 For the assignment of the **LMA** notation, calculations are to be carried out using the information specified in 1.3 to produce an estimation of the ship's manoeuvring capability which must satisfy the requirements of 2.3.

2.1.2 The calculations will normally be carried out by Lloyd's Register (hereinafter referred to as 'LR'), but may be carried out by the designer or Shipbuilder and submitted to LR for assessment together with the data specified in 1.3.

2.2 Manoeuvres to be assessed

2.2.1 The calculations are to give estimates of the primary manoeuvring indices from the following:

(a) Ship's turning circles to port and starboard with maximum design rudder angle starting from:
- The approach speed, *see* 3.4.1, coupled with a pull-out manoeuvre.
- Full sea speed and constant engine(s) control setting.
- Half manoeuvring ship speed and constant engine(s) control setting.

(b) Ship's stopping manoeuvring characteristics by the application of astern power, from:
- The approach speed, *see* 3.4.1.
- Full sea speed.
- Full manoeuvring speed ahead.
- Half manoeuvring speed ahead.
- Slow manoeuvring speed.

(c) Ship's yaw (rate of change of heading) checking characteristics through the 20º/20º and 10º/10º zig-zag manoeuvres, from the approach speed, *see* 3.4.1, with constant engine(s) control setting.

(d) Ship's initial turning ability at the approach speed, *see* 3.4.1.

(e) Where these manoeuvres indicate dynamic instability, additional representative manoeuvres may be required, for example, a spiral manoeuvre, *see* 3.5.2.

2.2.2 For the purpose of the calculations, thrust break-down due to cavitation during manoeuvring conditions and the effects of wind, tide, current and shallow water may be ignored.

2.3 Manoeuvring standards

2.3.1 For the assignment of the **LMA** notation, the ship is to be assessed in accordance with the requirements of IMO Resolution A.751(18).

2.3.2 In cases where a large displacement ship does not satisfy the stopping standard referred to in 2.3.1, special consideration will be given to the ship's stopping capability.

2.4 Model tests

2.4.1 Model tests may be carried out in lieu of calculations, provided that they reflect the conditions and manoeuvres defined in 2.2. A report is to be submitted which details the test arrangements, ship's characteristics as defined in 1.3, schedule of tests and results presented in both diagrammatic and tabular form.

2.5 Wheelhouse poster and manoeuvring booklet

2.5.1 The results of the calculations required by 2.2 (stating the assumptions made), together with additional information gained from the verification trials, and trial data for the man overboard manoeuvre, are to be presented in diagrammatic and tabular form and included in a wheelhouse poster and a manoeuvring booklet.

2.5.2 The poster is to be permanently displayed in the wheelhouse, and is to contain a clear warning that the data presented is applicable to calm weather with no wind, waves or current. The booklet is to be placed on board and is to contain comprehensive details of the ship's manoeuvring characteristics.

2.5.3 The format, data and content of the wheelhouse poster and the manoeuvring booklet are to meet the requirements of IMO Resolution A.601(15).

2.6 Manoeuvring information card

2.6.1 The manoeuvring information card is to contain a summary of the ship's manoeuvring capabilities and principal particulars and is to be kept on the wheelhouse for the information of the pilot. The format and data to be presented on this card are to satisfy the requirements of IMO Resolution A.601(15).

Section 3 Verification trials

3.1 General

3.1.1 For the assignment of the **LMA** notation, representative manoeuvres are to be carried out during sea trials, in accordance with the guidelines in Section 4, to verify estimates derived in Section 2.

3.1.2 Verification trials are normally to be performed with a clean hull and propeller in the presence, and to the satisfaction, of the LR Surveyor.

3.1.3 A report is to be submitted to LR detailing the test schedule and presenting the results of each manoeuvring trial in accordance with the guidelines in Section 4.

3.2 Environmental restrictions

3.2.1 The verification trials are to take place in deep, unconfined waters, to minimise the interactive effects of the sea bed topography. The water depth is not to be less than four times the mean operational draught of the ship. The windspeed should not exceed Beaufort 5 and wave sea state 4 should not be exceeded. Heavy swell is to be avoided.

3.2.2 The environmental conditions (wind, significant wave height, current and swell) are to be accurately recorded throughout the duration of the trials. The results of the trials are to be corrected to indicate the ship's manoeuvring capability under zero wind, waves and current.

3.3 Draught conditions

3.3.1 The trials are normally to be carried out with the ship in a normal operational condition within a five per cent deviation of the design draught and trim.

3.3.2 Where it is impractical to conduct trials at design draught, they may be conducted at a draught as close to the design draught as possible with minimum trim and sufficient propeller immersion.

3.3.3 Where trials are conducted in a condition other than that required by 3.3.1, the necessary manoeuvring characteristics are to be estimated for the trial and full load condition using an acceptable method, and the results are to be submitted to LR for assessment.

3.4 Approach conditions

3.4.1 The approach speed is to be at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum engine output.

3.4.2 Before the execution of the relevant manoeuvre, the ship must have run at constant engine(s) setting with minimum rate of change of heading (steady course).

3.5 Representative manoeuvres

3.5.1 Representative manoeuvres are to be carried out to an agreed trials code, and are to include the following:

(a) The performing of one turning circle to port and one to starboard with 35 degrees rudder angle (or the maximum rudder angle) for the following approach conditions:
- Conditions defined in 3.4, coupled with a pull-out manoeuvre.
- Full sea speed.
- Half manoeuvring speed.

(b) Ship's stopping manoeuvre from full ahead manoeuvring speed achieved by stopping the engine.

(c) Ship's stopping manoeuvre from full sea speed achieved by the application of full astern thrust.

(d) Ship's stopping manoeuvre from the approach conditions, defined in 3.4, achieved by the application of full astern power.

(e) A 10º/10º zig-zag manoeuvre, under the approach conditions defined in 3.4.

(f) A 20º/20º zig-zag manoeuvre, under the approach conditions defined in 3.4.

(g) Initial turning manoeuvre at the approach conditions defined in 3.4.

(h) Man overboard manoeuvre, such as the Williamson turn or an elliptical turn, to both port and starboard at full sea speed.

(j) Transverse thruster manoeuvres, if applicable, with the ship stopped and all thrusters at maximum power to turn the ship 180° to port and to starboard.

3.5.2 Provision is to be made in the trials agenda for the execution of a spiral manoeuvre where the results of the pull-out manoeuvre indicate excessive dynamic instability or the values for either the first or second overshoot angles, measured during the 10º/10º zig-zag manoeuvre, exceed the following:

L/V (seconds)	First Overshoot Angle (degrees)	Second Overshoot Angle (degrees)
<10	10	25
$10 \le L/V \le 30$	$5 + (0{,}5\ (L/V))$	$20 + (0{,}5\ (L/V))$
>30	20	35

where

L = length between perpendiculars (metres)

V = approach speed, defined in 3.4.1 (m/s).

■ *Section 4* Guidelines on conducting ship verification trials

4.1 General

4.1.1 These guidelines provide information on performing the verification trials in accordance with these Rules.

4.1.2 A detailed trials agenda is to be agreed before the commencement of any verification trials. This agenda should include:

- Agreement on the trials site.
- Notification of the possible restrictions that may be imposed by environmental conditions.
- A procedure to calibrate the data logging and measurement system.
- A procedure for data recording.
- The sequence in which the manoeuvring trials are to be conducted.
- The procedure for conducting each manoeuvre, including agreement on the starting and finishing points, the approach speeds and engine setting.

4.1.3 Environmental conditions can have a pronounced influence on the manoeuvring performance of a ship, therefore the verification trials are to be conducted within the environmental restrictions imposed by these Rules.

4.1.4 The following points are to be noted when determining the trials agenda:

- The ship's dynamic stability is required to be assessed in accordance with 3.5.2. It is recommended that the pull-out manoeuvre is performed at the end of the turning circle manoeuvres, *see* 4.5.
- The initial turning ability of the ship, required by 2.2.1(d), can be measured during the 10°/10° zig-zag manoeuvring trial, *see* 4.7.

4.2 Calibration of the data logging and measurement system

4.2.1 Before commencing the verification trials, the data logging and measurement system is to be calibrated. The allowable measurement tolerances and the frequency of each measurement are given in Table 6.4.1.

4.2.2 The measurement system's time and the ship's time are to be synchronized with a recognised time signal. The time and date, relative to Universal Time Constant (UTC), are to be recorded.

4.2.3 The position of the ship is to be determined by all available means and calibrated with range and/or bearing fixes from three prominent landmarks, including radar responding beacons (racons). Where the ship's position is to be measured using land-based transponders, the installation, set-up and calibration of such measurement equipment are to be carried out to the manufacturer's instructions.

4.2.4 The ship's speed over the ground is to be calibrated with range and/or bearing fixes from three prominent landmarks (including racons), whilst held on a steady course with no alteration in engine setting.

4.2.5 The gyro repeaters are to be adjusted until they are synchronized with the master gyro compass reading.

4.2.6 The steering gear is to be tested to calibrate the rudder angle indicator(s), over the full range of movement against the actual rudder angle reading given on the rudder stock.

4.2.7 The rate of turn indicator can be calibrated against the actual change in heading per second during a turn.

4.2.8 Where an automatic data logging and measurement system is to be used, the installation, set-up and calibration of such measurement equipment are to be carried out to the manufacturer's instructions.

Table 6.4.1 Data measurement and accuracy requirements

Parameter	Turning circles	Pull-out manoeuvres	Stopping manoeuvres	Zig-zag manoeuvres	Spiral manoeuvres	Man overboard manoeuvres	Minimum accuracy
Time	Continuously	Continuously	Continuously	Continuously	Continuously	Continuously	± 1 sec
Position	Initially, and then at least every 45 degree change of heading		Initially, and then at least every 20 secs	At least 5 equally spaced measurements		Initially, then at least every 45 degree change of heading or 20 secs whichever is the lesser	± 10 metres
Forward speed	At least every 10 secs or 30 degree change of heading		At least every 5 secs	At least every 5 secs	Initially, then once at each steady rate of turn	At least every 5 secs	± 0,5 knots
Heading	At least every 5 secs	At least every 2 secs	At least every 20 secs	At least every 2 secs	At least every 2 secs	At least every 2 secs	± 0,5 degrees
Rudder angle	Initially, and then at least every 45 degree change of heading	At least every 2 secs	Initially, and then periodically to check the rudder is amidships	At least every 2 secs	One for each steady rate of turn	At least every 5 secs	± 1 degree
Engine RPM	Initially, and then at least every 45 degree change of heading		Initially, and then at least every 5 secs	Initially, and then at least at every crossing of the base course	Initially, and then once at each steady rate of turn	Initially, then when the rudder is reversed and at the end of the manoeuvre	± 1% of initial setting
Rate of turn	At least every 5 secs	At least every 2 secs		At least every 5 secs	At least every 5 secs		± 0,05 degrees/sec

NOTE
All parameters are to be measured at the initiation and termination points of each manoeuvring trial.

4.2.9 The equipment used to measure prime mover/ propeller shaft revolutions and shaft power (torsion meters) is to be calibrated before trials.

4.3 Data recording

4.3.1 The data describing manoeuvring performance is to be measured and recorded in accordance with the requirements of Table 6.4.1. This data is to be measured and recorded from the start of the approach run and terminated at the end of the manoeuvring trial. The start of the manoeuvring trial is to be defined by a specific engine order or helm change noted on the recorded measurements.

4.3.2 An automatic data logging and measurement system is the preferred option. However, where the manoeuvring data is to be recorded manually, it is necessary to have suitable indicators and repeaters available to allow a sufficient number of persons to record the required parameters. Sufficient personnel are to be present to ensure that each person is recording no more than three parameters in each trial.

4.3.3 All recordings are to be synchronized to a common time datum.

4.3.4 The following data is to be clearly recorded for each trial manoeuvre:

(a) Date.
(b) Time.
(c) Ship's loading condition (draught and trim).
(d) Initial approach speed and heading.
(e) Water depth.
(f) Environmental conditions, including:
 current speed and direction;
 wind speed;
 wind direction relative to the ship's head;
 sea state.
(g) Position (latitude and longitude) (The use of calibrated GPS systems is acceptable.)
(h) Ship's heading.
(j) Rate of turn.
(k) Speed.
(l) Rudder angle.
(m) Propeller revolutions.
(n) Propeller pitch, where applicable.

4.3.5 The steady approach conditions for each trial are to be recorded for at least two minutes before the initiation of the manoeuvring trial.

4.4 Turning circle manoeuvring trials

4.4.1 These trials measure the effectiveness of the rudder(s) in initiating a turn and the ship's steady state turning characteristics.

4.4.2 The turning circle manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
 (i) the relative approach condition defined in 3.5.1(a) is satisfied and the ship is running head to wind; and
 (ii) the rudder is ordered hard over to port or starboard.
(b) It must continue without any alteration to the engine control settings.
(c) It is to be terminated when the ship has completed a 540° turn.

4.4.3 The following information is to be derived from the trials data, *see* Fig. 6.4.1:

(a) Time taken to reach each 90° change of heading.
(b) Advance at each 90° change of heading.
(c) Transfer at each 90° change of heading.
(d) Tactical diameter.
(e) Steady turning diameter.
(f) Loss in forward speed during the turn.
(g) Rate of turn during the turn, *r*, *see* 4.9.5.

4.5 Pull-out manoeuvring trials

4.5.1 The pull-out manoeuvre is a simple trial which has been developed to give a quick indication of the ship's course keeping ability. The pull-out manoeuvre is to be performed at the end of each turning circle manoeuvring trial. The results of these manoeuvres will indicate whether a spiral manoeuvre trial is required to be conducted, *see* 4.9.

4.5.2 The pull-out manoeuvre is to be conducted as follows:

(a) The ship is to be in a steady state turn (constant rate of turn) with the rudder hard over. This manoeuvre is normally conducted on the termination of the turning circle manoeuvring trial.
(b) This manoeuvre is initiated when the rudder is ordered amidships.
(c) With the rudder held amidships, the rate of turn will decrease.
(d) If the ship possesses 'dynamic stability', the rate of turn will reduce towards zero with equal residual rates of turn for both port and starboard turns with the rudder held amidships. If there is an unequal residual rate of turn with the rudder held amidships, then the ship is to be considered 'dynamically unstable', *see* Fig. 6.4.2.

4.5.3 The following information is to be derived from the trials data, and presented as shown in Fig. 6.4.2:
 A plot of the time histories of the ship's head, rate of turn and ship's speed.

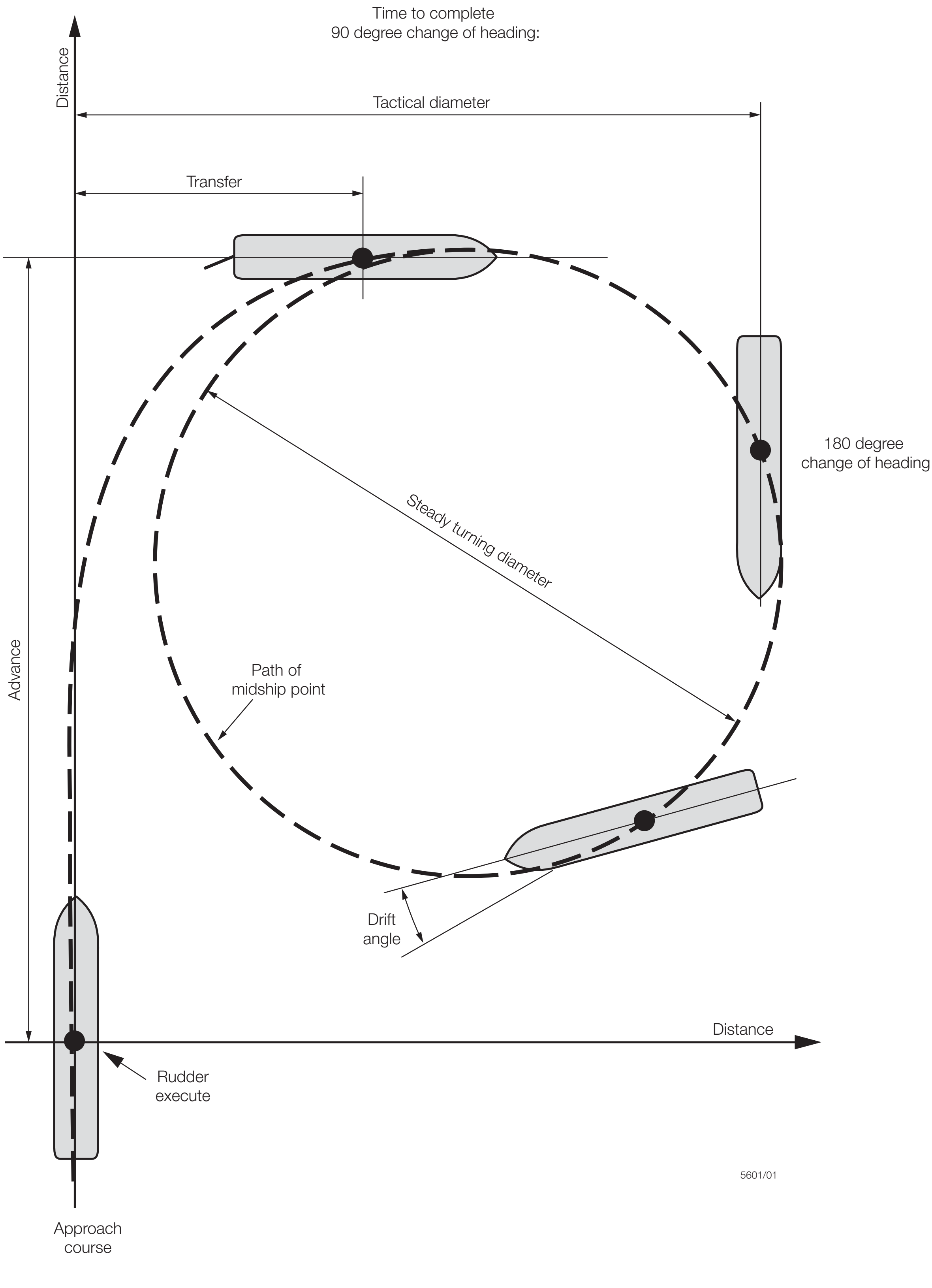


Fig. 6.4.1 Presentation of turning circle manoeuvring trial results

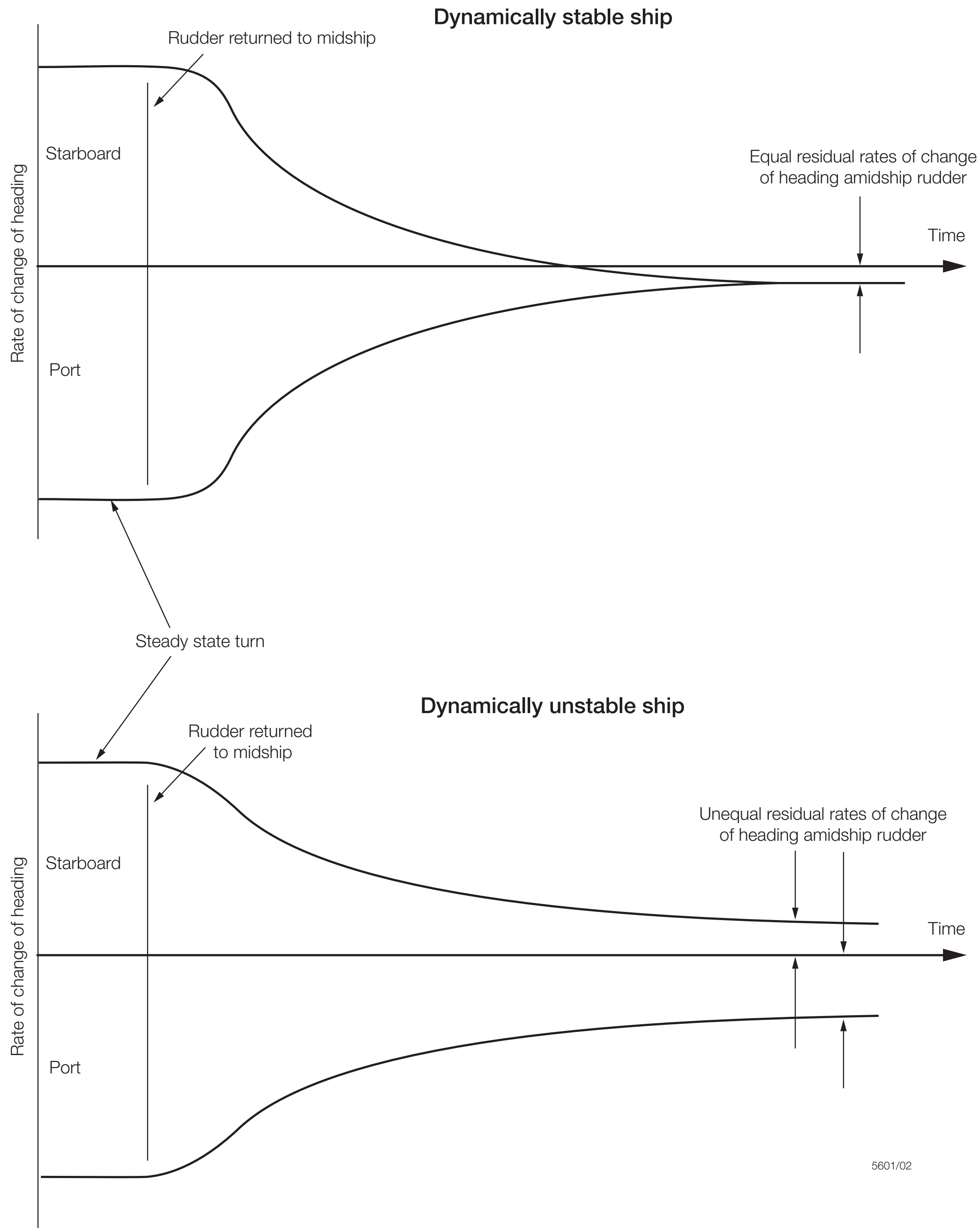


Fig. 6.4.2 Presentation of pull-out manoeuvring trial results

4.6 Stopping trials

4.6.1 A ship's stopping performance is normally represented by the crash stop manoeuvre, which determines the stopping ability of the ship from the time an order of full astern is given until the ship stops dead in the water for a given approach speed. In addition to the crash stop manoeuvre, a coasting stop manoeuvre is required to be conducted with the engines delivering no power to the propeller.

4.6.2 The stopping manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
   (i) the relative approach conditions defined in 3.5.1(b) or (c) are satisfied and the ship is running with the wind astern, and
   (ii) the demand for full astern power or stop is given from the engine control position on the bridge.

(b) The rudder is to be used to a minimal extent and only to keep the ship on course for as long as possible.

(c) It is to be terminated when the ship has stopped dead in the water.

4.6.3 The following information is to be derived from the trials data, *see* Fig. 6.4.3:

(a) Minimum speed at which course can be maintained.
(b) Head and track reach.
(c) Lateral deviation and final heading.
(d) Time to stop dead in the water.

4.7 Zig-zag manoeuvring trials

4.7.1 These trials measure the effectiveness of the rudder(s) to initiate and check changes in heading. This manoeuvre is normally defined as a θ_1/θ_2 zig-zag manoeuvre (e.g. 20º/20º) where:

(a) θ_1 is the required rudder angle, in degrees, to be applied during the trial, and
(b) θ_2 is the deviation, in degrees, of the ship's head, from the original course, before application of θ_1 to check changes in heading.

4.7.2 The zig-zag manoeuvre involves the cyclic movement of the ship about an initial base course. The zig-zag manoeuvre is conducted as follows:

(a) It is to be initiated when:
   (i) the approach conditions defined in 3.5.1(e) or (f) have been satisfied and the ship is running head to wind; and
   (ii) the rudder is ordered to θ_2 degrees to starboard (or port).

(b) It must continue without any alteration to the engine control settings.

(c) When the heading has changed by θ_2 degrees from the original course, the rudder is to be ordered to the opposite angle θ_1 degrees to port (or starboard).

(d) When the heading has changed by θ_1 degrees from the original course, the rudder is to be ordered to the opposite angle θ_2 degrees to starboard (or port).

(e) This manoeuvre is to be terminated when the ship's head has crossed the base course at least three times.

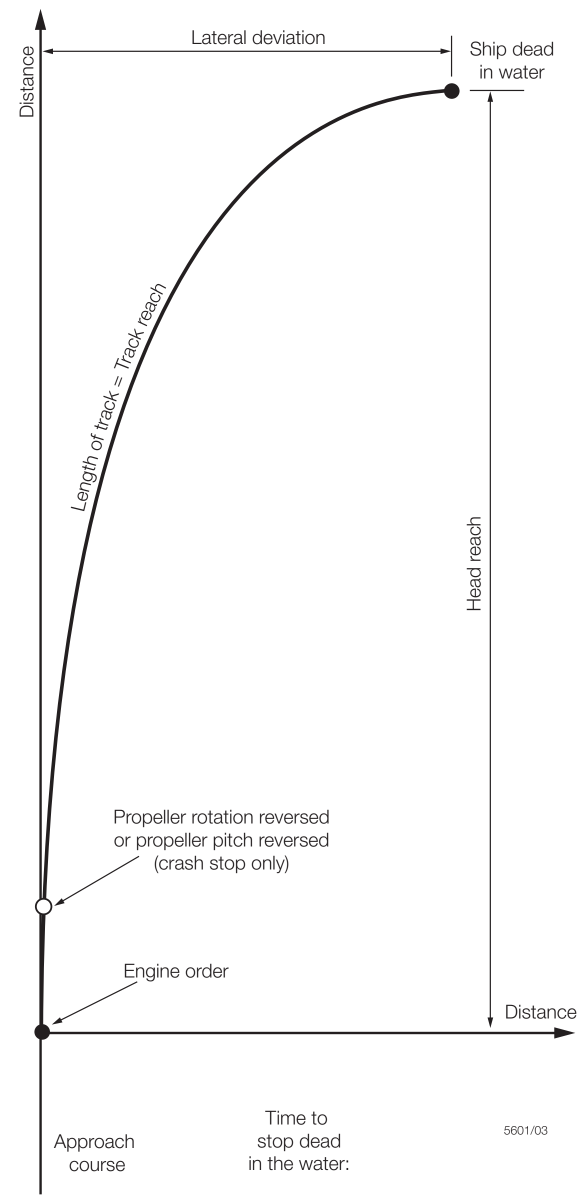
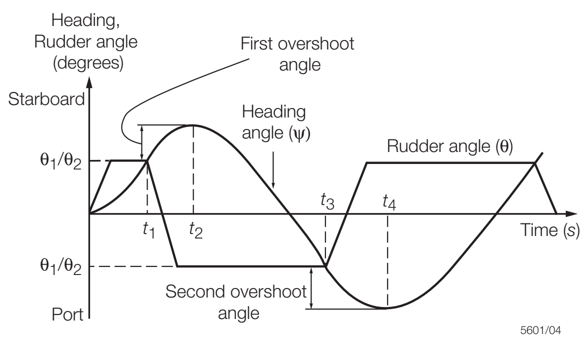


Fig. 6.4.3
Presentation of both stopping trials' results

4.7.3 The following information is to be derived from the trials data, *see* Fig. 6.4.4:

(a) A plot of the time histories of the rudder angles and corresponding ship's heading.
(b) First overshoot angle.
(c) Second overshoot angle.
(d) Time to check yaw (rate of change of heading equals zero) at each rudder reversal.
(e) Initial turning time.



t_1 = Initial turning time
$t_2 - t_1$ = Time to correct heading at first overshoot angle
$t_4 - t_3$ = Time to correct heading at second overshoot angle

Fig. 6.4.4
Presentation of zig-zag manoeuvring trial results

4.8 Initial turning manoeuvring trials

4.8.1 The initial turning manoeuvring trial measures the transient effectiveness of the rudder(s). To ascertain the ship's initial turning ability, in accordance with 2.2.1(d) and 3.5.1(g), the following data is to be recorded from the 10º/10º zig-zag manoeuvring trials:

When the ship's head has moved 10º off the base course, after the initial rudder command, the number of ship lengths travelled is to be recorded.

4.9 Spiral manoeuvring trials

4.9.1 This trial measures the ship's steady state rate of turn as a function of the applied rudder angle, providing a qualitative measure of the ship's dynamic stability.

4.9.2 There are two possible manoeuvring trials that can be used to assess the ship's dynamic stability, namely:

The direct, or Dieudonne, spiral manoeuvre.
The reverse, or Bech, spiral manoeuvre.

4.9.3 The direct spiral manoeuvre will yield more information about the degree of instability. However, this manoeuvre is very time-consuming, requires good weather conditions and, for larger ships, needs considerable sea room. The reverse spiral manoeuvre provides a procedure for defining the instability loop more rapidly than the direct spiral manoeuvre. However, this trial requires accurate rudder angle and rate of turn indicators. Where the ship is to be steered manually, the helmsman is to be able to read the rate of turn indicator.

4.9.4 Te direct spiral manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
  (i) the approach conditions defined in 3.4 have been satisfied, and
  (ii) the rudder is ordered to 25º to starboard.
(b) It must continue without any alteration to the engine control settings.
(c) The rudder is to be held until the rate of turn is assumed constant.
(d) The rudder angle is then to be decreased by 5º and held until the rate of turn is assumed constant.
(e) The manoeuvre is to be terminated when the rudder has moved through the range of 25º to starboard to 25º to port and then back to 25º to starboard in incremental rudder angles of 5º.
(f) For dynamically unstable ships, the incremental rudder angle in the range of 10º to starboard through to 10º to port is to be 2º.

4.9.5 The reverse spiral manoeuvre is to be conducted as follows:

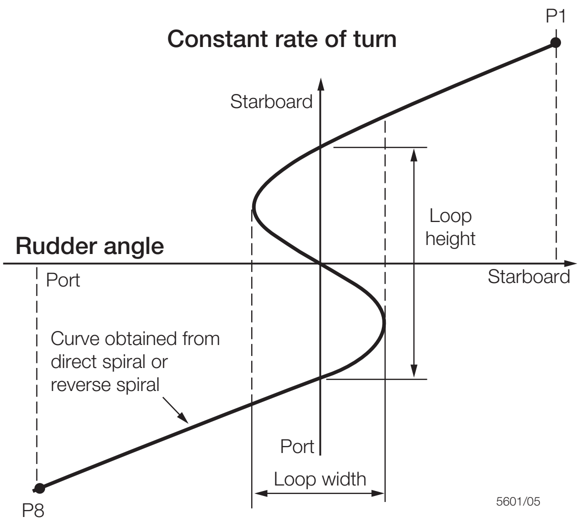
(a) It is to be initiated when:
  (i) the approach conditions defined in 3.4 have been satisfied; and
  (ii) the first constant rate of change of heading is achieved.
(b) It must continue without any alteration to the engine control settings.
(c) The recommended constant rates of turn are defined as percentages of the steady state rate of turn, *r*, derived from the turning circle, as shown in Table 6.4.2.
(d) The points P1 to P8 represent positions on the spiral curve, *see* Fig. 6.4.5.
(e) The first and last points on the spiral curves (P1 and P8) can be derived from the turning circle manoeuvres.
(f) The ship is to be steered at a constant rate of turn and the mean rudder angle to achieve the desired rate of turn is to be noted. The rudder angle deviations are not to be greater than ± 2º.
(g) The manoeuvre is to be terminated when all points have been determined.

Table 6.4.2 Recommended constant rate of change of heading

Points	Rate of change of heading
P1 and P8	1,0 *r*
P2 and P7	0,6 *r*
P3 and P6	0,3 *r*
P4 and P5	0,1 *r*
where *r* = change of heading per second = $\frac{d\psi}{dt}$	

4.9.6 The following information is to be derived from the trials data, *see* Fig. 6.4.5:

(a) A time history of the rudder angle and corresponding rate of turn.
(b) A plot of the constant rate of turn as an ordinate against the applied rudder angle.



P1, P8 Rate of turn at maximum rudder angle
P2 to P7 Intermediate points which will form the curve which will represent the ship's dynamic stability, *see* Table 4.2

Fig. 6.4.5
Presentation of spiral manoeuvring trial results for a dynamically unstable ship

4.10 Man overboard manoeuvring trials

4.10.1 The man overboard manoeuvre provides the Master with important information on the time taken and the deviation from course necessary to retrieve a person or object from the sea. The elliptical and Williamson turns are two well-known man overboard manoeuvres. These manoeuvres will, in the absence of wind and current, bring the ship back to the position where the man overboard incident occurred.

4.10.2 The elliptical turning manoeuvre is to be conducted as follows:
(a) It is to be initiated when:
 (i) the approach conditions defined in 3.4 have been satisfied, and
 (ii) the rudder is ordered hard over.
(b) It must continue without any alteration to the engine control settings.
(c) The rudder is to remain hard over until the ship has altered course by 180º. The ship is to be steadied on the reciprocal heading until the approach speed has been regained.
(d) The rudder is once again placed hard over and the ship is steadied on the original course.
(e) This manoeuvre is to be terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

4.10.3 The Williamson turning manoeuvre is considered quicker than the elliptical turning manoeuvre in returning the ship to the original man overboard position. This manoeuvre is to be conducted as follows:
(a) It is to be initiated when:
 (i) the approach conditions defined in 3.4 have been satisfied, and
 (ii) the rudder is ordered hard over.
(b) It must continue without any alteration to the engine control settings.
(c) The rudder is to remain hard over until the ship has altered course by 70º. The rudder is then ordered hard over to the opposite side, until the ship is on a course which is the reciprocal of the original approach course.
(d) It is terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

4.10.4 The following information is to be derived from the trials data, *see* Fig. 6.4.6:
(a) A plot of the ship's track.
(b) The time taken to return to the point, or nearest position to that point, at which the manoeuvre was initiated.
(c) The lateral deviation from the initial course at the point, or nearest position to that point, at which the manoeuvre was initiated.

4.11 Manoeuvring trials for auxiliary thrusters

4.11.1 Where a ship is fitted with auxiliary thrusters, such as bow thrusters, a turning circle manoeuvre is required to be performed in accordance with 3.5.1(j) to determine the effectiveness of those thrusters in turning the ship through 180º. This trial is to be carried out with the wind initially from the stern and the ship turning into the wind.

4.11.2 The auxiliary thrusters' turning circle is to be conducted as follows:
(a) All primary thrusters stopped and the ship dead in the water.
(b) The ship is to be completely stopped in the water with head to wind.
(c) The auxiliary thrusters are to be set to maximum power to turn the ship.
(d) The manoeuvring trial is to be completed when the ship has turned through 180º.

4.11.3 The following information is to be derived from the trials data:
(a) The time taken to reach a 90º change of heading.
(b) The time taken to reach a 180º change of heading.
(c) The transfer at a 90º change of heading, *see* Fig. 6.4.1.
(d) The transfer at a 180º change of heading, *see* Fig. 6.4.1.
(e) The steady state rate of change of heading.

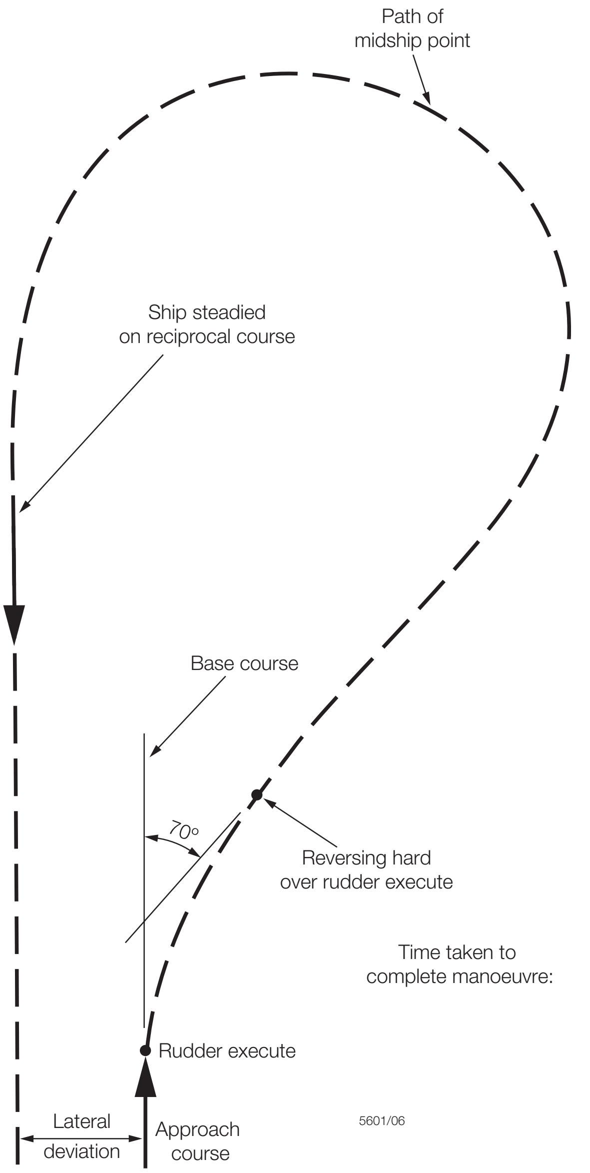


Fig. 6.4.6
Presentation of the Williamson turn, man overboard, manoeuvring trial results

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter states the requirements for Replenishment At Sea (RAS) systems installed in naval ships for the purpose of receiving solid or liquid supplies. The Chapter also states the requirements for Vertical Replenishment (VERTREP) and light jackstay RAS systems which may be used for transfer of personnel and light stores between naval ships. The requirements are in addition to the relevant requirements contained in Volumes 1 and 2 of these Rules. Other arrangements to supply solid and liquid stores by means of RAS will be specially considered.

1.1.2 The requirements in this Chapter cover arrangements, deck equipment, piping and control systems necessary for RAS operations.

1.1.3 The extent of RAS systems and facilities are subject to agreement between the Designer and Owner/operator. The classification approval process will involve assessment of the safety of the proposed facilities from concept to through life operability and de-commissioning. RAS operations are extremely hazardous and those involved in the development of such systems need to address safety issues to minimise the risks to the ship, personnel and the environment. Operational procedures and regular crew training are essential to minimise these risks and reducing hazards to as low as reasonably practicable.

1.1.4 The Naval Authority may impose requirements additional to those in this Chapter.

1.1.5 NATO interoperability requirements are to be specified by the Owner/Operator and are detailed in APT16 (latest version).

1.2 RAS terminology

1.2.1 RAS terminology is defined in 1.2.2 to 1.2.9.

1.2.2 **RAS station**: The physical location of a combination of deck area and associated equipment that provides a ship with the capability to receive or deliver solids, liquid or personnel by means of passing RAS equipment between ships whilst underway. Note these Rules are only applicable to naval ships intended for receiving solid or liquid supplies.

1.2.3 **VERTREP Operational Area (VOA)**: This is the authorised area within which VERTREP operations are conducted. It includes the clear deck space for helicopter rotor, fuselage and landing gear, and VERTREP load clearances (including dump areas).

1.2.4 **Abeam Replenishment**: The transfer of solid cargo or personnel or liquid cargo by means of passing RAS equipment between ships while underway and with the Receiving Ship maintaining station abeam of the Supplying Ship.

1.2.5 **Astern Replenishment**: The transfer of liquid cargo by means of a hose(s) while underway with the Receiving Ship maintaining station astern of the Supplying Ship.

1.2.6 **Vertical Replenishment (VERTREP)**: Transfer of solid cargo and personnel by underslung load from a helicopter.

1.2.7 **Supplying Ship**: The ship that supplies the RAS equipment and cargo.

1.2.8 **Receiving Ship**: The ship that receives the RAS equipment and transferred cargo.

1.2.9 **Dump Area**: A designated clear area that is provided at VERTREP and Abeam RAS stations for receiving stores.

1.3 Safety

1.3.1 Replenishment at sea between two vessels underway (particularly abeam RAS) is classified as the most hazardous peacetime seamanship evolution conducted by the naval and supply ships. It is important that the following areas are considered when designing, building, operating and maintaining RAS systems:

(a) **Close Proximity of Vessels Underway**: Station keeping and the availability of propulsion and steering to maintain constant speed and heading are vital to avoid collision, due to the pressure interaction areas between ships in close proximity underway.

(b) **Handling of Explosives and Bulk Ammunition**: Replenishment of solids includes ammunition classified as UN hazard category 1.1, and particular note is required of the enhanced factors of safety and equipment test periodicities that are required for mechanical handling equipment used for ammunition.

(c) **Transfer of Personnel and Explosives**: Lifting appliance codes of practice stipulate enhanced factors of safety and more frequent testing for preventative maintenance of mechanical handling equipment used for transfer of personnel and explosives.

(d) **Safety of Personnel**: Care is to be taken in the design and operation of RAS systems to minimise hazards to personnel who have to work in the vicinity of the RAS station. The likelihood of personnel being injured or knocked overboard by RAS equipment and operating gear is to be assessed and suitable guard rails are to be provided as necessary.

■ *Section 2* Principles

2.1 Design and operating principles

2.1.1 RAS systems are to be designed in accordance with user defined operating and performance criteria taking account of the ship type and service operating envelope.

2.1.2 RAS systems are to be capable of operation within specified operating conditions that include maximum sea states, wind conditions and those identified in Vol 2, Pt 1, Ch 2,4.

2.1.3 RAS systems are to be designed and installed such that degradation or failure of any RAS system will not render another system inoperable.

2.1.4 RAS systems are to be capable of operating within the normal vibration modes and cyclic loads of the ship.

2.1.5 RAS systems are to be designed to minimise the risks to ship, personnel and the environment. The risks involved in carrying out identified hazardous activities are to as low as reasonably practicable.

2.2 Lifecycle principles

2.2.1 RAS systems are to be operated and maintained such that the required performance, integrity and dependability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the Provisions of Classification for engineering systems (*see* Vol 2, Pt 1, Ch 1,2.1.1), surveys are to carried out in accordance with the Regulations and as detailed in Section 14.

2.3 Class notations

2.3.1 Ships complying with the applicable requirements of this Chapter will be eligible for machinery class notations.

RAS(ABV):	Ships having arrangements to enable RAS operations astern, abeam and VERTREP.
RAS(AB):	Ships having arrangements to enable RAS operations abeam and astern only.
RAS(AV):	Ships having arrangements to enable RAS operations astern and VERTREP.
RAS(BV):	Ships having arrangements to enable RAS operations abeam and VERTREP.
RAS(A):	Ships having arrangements to enable RAS operations astern only.
RAS(V):	Ships having arrangements to enable RAS operations VERTREP only.

2.3.2 Where ships comply with NATO replenishment at sea requirements, the requirements of this Chapter will be eligible for an additional character (**NT**) following any of the notations described in 2.3.1. The Naval Authority is to identify the relevant standard(s) (STANAG(s)) for assignment of the (**NT**) notation with reference to the arrangements being applied from 2.3.1. Assessment for compliance with the identified standard will address the safety and design/operating principles in these Rules.

■ *Section 3* Acceptance criteria

3.1 General

3.1.1 The acceptance process will validate conformity of RAS systems and equipment to the provisions of classification for systems within the Ship Type category by assessing such systems for compliance with Lloyd's Register (hereinafter referred to as 'LR') Rules and Regulations or their equivalent, and specified standards and codes.

3.1.2 The assessment process of RAS systems will consider all aspects of the system including ship to ship dynamic interaction and environmental effects.

3.1.3 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the Designer/Builder and Owner/Operator to the satisfaction of LR.

3.1.4 For RAS operations, the applicable Rules, Standards for classification are:
(a) LR Rules for the Classification of Naval Ships.
(b) LR's *Code for Lifting Appliances in a Marine Environment*.
(c) Requirements of the Naval Authority, *see* 3.1.5.
(d) Owner/Operator specified requirements. These are to be identified before commencement of the design review or construction.
(e) Standards for transfer hoses.
(f) LR Type Approval System.
(g) LR Quality Scheme for Machinery.

3.1.5 Where LR is acting on behalf of the Naval Authority, any relevant requirements of the Naval Authority are to be identified and advised to LR.

■ *Section 4* Design and construction

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of RAS systems are:
(a) LR's Rules for RAS systems.
(b) The equipment manufacturer's recommendations.
(c) NATO Replenishment at Sea documents where specified by the Owner/Operator.

4.1.2 The overall performance of RAS systems is to be demonstrated to conform with the performance criteria specified in the design statement.

4.2 Functionality

4.2.1 In general, NS1 and NS2 type ships are to be configured such that replenishment of solids and liquids can be conducted concurrently. Ships are to be capable of supplying and receiving RAS equipment such that they can transfer personnel by abeam replenishment. For abeam RAS operations a minimum of four RAS stations (two port and two starboard) should be provided, (for larger ships six RAS stations may be incorporated). For astern RAS operations at least one station should be provided on the fo'c'sle.

■ *Section 5* Plans and particulars to be submitted

5.1 Plans and information

5.1.1 Three copies of the plans and information stated in 5.1.2 to 5.1.10 are to be submitted to LR as applicable.

5.1.2 **Design statement**. A design statement of the RAS systems that details the capability and functionality under defined operating and emergency conditions. The design statement is to agreed between the Designers and Owners/ Operators and is to include as applicable:
(a) Required class notations.
(b) Details of intended supply ships.
(c) Description of each RAS operation and combination of equipment required.
(d) Plans showing each proposed combination of equipment, fully rigged.
(e) Details of solids that may be received (maximum size and weight together with UN hazard category if applicable).
(f) Details of liquids that may be received (including flash point of oils and transfer rates).
(g) Details of the range of sea and environmental conditions under which each RAS operation may be undertaken.
(h) Interoperability capability.
(j) Manning requirements.
(k) Details of arrangements for RAS operations in darkness.

5.1.3 **Engineering and safety justification**. An engineering and safety justification for the RAS systems stating design standards and assumptions and providing technical evidence. The justification is to:
(a) State all design standards used for the design, manufacture, installation and testing of RAS systems and equipment.
(b) Provide details of all RAS equipment and compatibility of different items of equipment.
(c) Provide evidence that all RAS operations (equipment and combinations) at each RAS station as identified in the design statement, can be carried out safely and in accordance with classification and equipment manufacturer's requirements.
(d) Identify safe equipment configurations.
(e) Provide calculations that demonstrate that the structural loading is in accordance with Rule requirements.
(f) Provide calculations that demonstrate that equipment loads are in accordance with manufacturer's specified limits.
(g) Provide evidence that sufficient control, monitoring and communication facilities are provided to conduct RAS operations safely and efficiently.
(h) Examine the dynamic behaviour (e.g. roll period, steering response, tendency to yaw, etc) of all the supplying ships identified to conduct RAS operations and draw up operational limits that define when RAS operations are not to be conducted between ships when this will result in possible dangerous hull interactions. Limits are to be defined in terms of lateral separation between vessels, wind force, sea conditions (height, swell and direction) and environmental conditions (visibility).
(j) Examine the effect of environmental conditions (e.g. sea state, water depth, visibility, wind strength, etc.) on the proposed RAS operations and define limiting conditions and define limiting environmental conditions for each RAS operation.
(k) Address the specific needs of emergency breakaway and demonstrate that such a procedure can be undertaken with all RAS equipment configurations at each RAS station.

(l) Provide evidence that the ship internal, ship to ship and ship to helicopter communications systems will allow safe and efficient communications and RAS operations. The communications equipment and systems provided are to take into account the design of the ship and intended method of operation. Redundancy is also to be considered.
(m) Provide evidence that each system is designed to minimise the risks associated with handling the particular cargo (e.g. static electricity with aviation fuel).

Where applied standards are not in the public domain, e.g. ATP 16(latest version) covering NATO Replenishment at Sea, a copy is to be included with the engineering and safety justification.

5.1.4 **General arrangement plan**. A general arrangement plan of the ship showing the following information:

(a) Position of each RAS station, with identifiable reference to the engineering and safety justification and design statement.
(b) The tasks to be carried out at each RAS station.
(c) Position of observation and control positions.
(d) Arcs of fields of view and operation from each of the observation and control positions and RAS stations.

5.1.5 **Structural plans**. Plans required by Vol 1, Pt 4, Ch 1,5 and Ch 2,9.

5.1.6 **Fluid transfer plans and particulars**. Plans in diagrammatic form showing filling arrangements from the filling connection to filling trunks (where installed) and subsequently to each storage tank. The plans are to include a statement of the minimum flash point (closed cup test) and the maximum transfer/filling rates.

5.1.7 **Lifting appliances**. Plans and details of all lifting appliances as required by LR's *Code for Lifting Appliances in a Marine Environment* or other specified design code.

5.1.8 **RAS equipment**. Details of equipment identified for RAS operations. Design and installation loads on the equipment together with details of securing and holding down arrangements. Details of the access required for maintenance and to operate the equipment.

5.1.9 **Operating manuals**. Operating manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars and a description of each RAS system.
(b) Operating and maintenance instructions for all equipment.
(c) Matrix of safe combinations of equipment and details of permitted load that may be carried by each combination.
(d) Test procedures for each system.
(e) Details of valve and pipe configurations when transferring fluids.
(f) Details of arrangements for transfer of solids and personnel.
(g) Details of night operations.

5.1.10 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in the design statement.

■ *Section 6* **Ship and arrangement requirements**

6.1 Location of RAS stations and equipment

6.1.1 Designated RAS stations are to be provided for RAS operations. The number, type and location of these stations is to be agreed between the Designer and Owner/Operator. As a guide, for NS1 and NS2 type ships, it is usual practice to have six abeam RAS stations (three port and three starboard) located symmetrically about the ship's centre line with one of these located on the fo'c'sle to enable replenishment of ammunition direct to the fo'c'sle.

6.1.2 Each RAS station and the particular RAS operation(s) that may be carried out at the station is to be identified on the general arrangement plan.

6.1.3 Where possible an abeam RAS station is to be located amidships to maximise crew protection during RAS operations during heavy weather conditions.

6.1.4 RAS stations are to be located so as to permit the observation of each RAS station from two observation positions. In general the positions selected for the abeam RAS stations are to be port and starboard in the middle portion of the ship between 20 m and 40 m apart symmetrically positioned from amidships and set in so as to provide protection for the RAS crews in heavy seas.

6.1.5 Clear areas are to be provided at each RAS station. Sufficient clear area to enable safe and efficient operation of equipment is to be provided. The area available is to recognise the equipment manufacturer's recommendations for operations is to be contained within 30º fore and aft of the normal transverse at the RAS station.

6.1.6 The location of all rigging securing points is to comply with the equipment manufacturer's requirements and agreed between the Designer and Owner/Operator.

6.1.7 Clear and safe access to all rigging securing points is to be provided. Arrangements are to be provided to ensure that access to those securing points high on the superstructure can be reached safely and speedily. The arrangements are to be such that there is no requirement for personnel to climb masts to gain access to RAS high points.

6.1.8 The access arrangements to all securing points are not to expose crew to dangerous electromagnetic hazards, *see* Vol 2, Pt 1, Ch 2,4.18.

6.1.9 In the selection and design of an abeam RAS position for a particular ship, for either a supply or receiving rig, the range of ships with which the ship can operate is to be considered so that the respective stations can be aligned transversely within ±5° of the normal, without the amidships points of the receiving ship moving further forward than $L/10$ and $L/5$ aft of amidships of the supply ship. (Where L is the length of the supply ship.) *See* Fig. 7.6.1.

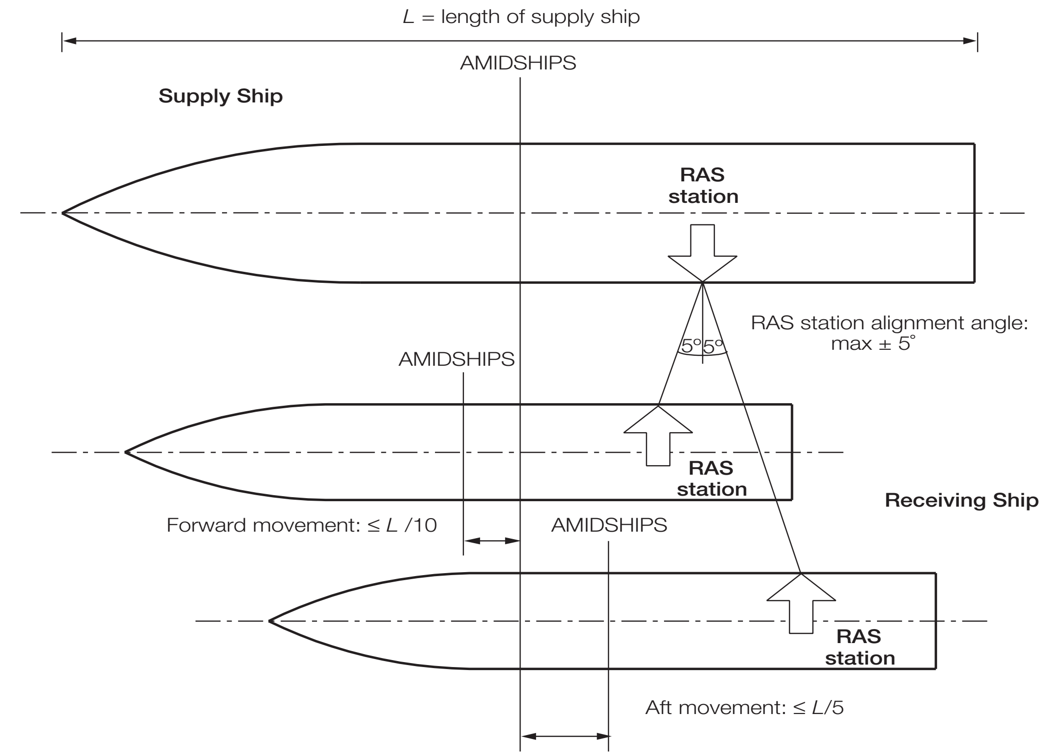


Fig. 7.6.1 Alignment of RAS stations

6.1.10 RAS stations are to be provided such that when two simultaneous RAS operations are being conducted, liquids can be transferred aft of solid cargo.

6.1.11 For requirements relating to electrical equipment for use in explosive gas atmospheres, *see* Vol 2, Pt 10, Ch 1,13.

6.2 RAS observation positions

6.2.1 Designated RAS observation positions are to be provided. Each observation position is to be sited to provide a clear field of view of all RAS operations at a particular RAS station. Each RAS station is be capable of being observed from at least two observation positions.

6.2.2 Each RAS observation position is to be identified on the general arrangement plan. Arcs showing the field of view from each observation position are also to be shown on the general arrangement plan.

6.2.3 Safe access arrangements to each observation position are to be provided.

6.2.4 Each observation position is to be provided with:

(a) The necessary communication equipment to enable speedy and efficient communication to ensure safe RAS operations.

(b) Equipment to prevent personnel falling or being knocked overboard and a strong point for attachment of a harness arrangement.

6.3 RAS equipment store arrangements

6.3.1 Dedicated store arrangements are to be provided for the storage of RAS equipment and fittings. Stores are to be readily accessible from the weather deck and their respective RAS stations.

6.3.2 RAS equipment and fittings associated with potable fresh water RAS operations are to be provided with separate, clean, hygienic and secure conditions.

6.4 Position of radar units and other sources of electromagnetic energy

6.4.1 RAS stations, observation positions and securing points are as far as practicable to be sited clear of sources of electromagnetic energy such as radars, communication transmitters, or lightning conductors. Where such equipment or the swept beam from radar aerials is in close proximity to any RAS facilities, a risk assessment is to be undertaken to ensure that the dangers of RADHAZ are minimised.

6.5 Location and layout of stores

6.5.1 The number, type and location of stores are to be consistent with the routes leading to/from RAS stations. The layout of each store is to recognise the need to rapidly strike down equipment and provisions and are to be agreed between the Designer and Owner/Operator.

6.5.2 The routes from RAS stations to stores are to be designed to simplify loading of stores, equipment and provisions during RAS operations. The arrangements are to recognise minimising tripping hazards and the need for two people to pass without restriction.

6.5.3 The entrances to the interior of the ship from each RAS station are to be designed to prevent the ingress of seawater when undertaking RAS operations in heavy weather conditions.

6.6 Ship's structure

6.6.1 Each RAS station that is designed to receive solids during RAS operations is to have a designated dump area. The dump area is to be suitably stiffened and designed to withstand the impact loads that may arise whilst landing stores and equipment on board during RAS operations.

6.6.2 The extent of each dump area is to exceed the foot print of the largest pallet by not less than 1 metre in each direction. A factor of safety of not less than four times the maximum load to be transferred is to be used in the design of the structure.

6.6.3 The location of the dump area within the RAS station is to be agreed between the Designer and Owner/Operator and is to centre on the high point where applicable.

6.6.4 For other structural requirements, *see* Vol 1, Pt 4, Ch 2.

6.7 Sources of high intensity noise

6.7.1 RAS stations, observation positions and securing points are to be sighted such that exposure to high intensity noise (above 85db) for personnel involved in RAS operations is as low as reasonably practicable.

■ *Section 7* Ship operating system requirements

7.1 Bridge conning position

7.1.1 A conning location for the officer in charge of RAS operations is to be provided on the navigating bridge with a duplicated position on both bridge wings. The location is to be agreed between the Designer and Owner/Operator and be included in the design statement.

7.1.2 From the conning position, the officer in charge is to be able to observe the ship's heading and the relative movement of the two ships conducting RAS operations. Also, a gyro compass readout and rudder angle indicator are to be readily visible from the conning position.

7.1.3 The Naval Authority may require an additional emergency conning position for use in the event of the bridge conning position being out of service. The location and arrangements are to be agreed between the Designer and Owner/Operator and included in the design statement.

7.2 Machinery redundancy

7.2.1 The design of the propulsion and steering machinery is to provide arrangements that will permit RAS operations to be undertaken at minimum risk recognising a single failure in equipment associated with continuous propulsion and steering capability. The requirements of the machinery class notation **PSMR** in Chapter 5 are to be complied with as applicable. As a guide, ships are to be designed to be capable of maintaining continuous course and speed for at least one minute to facilitate safe emergency breakaway in the event of equipment failure in propulsion and steering systems.

7.3 Seakeeping and manoeuvrability

7.3.1 The seakeeping and manoeuvrability characteristics of the ship are to be assessed and the requirements of the class notation **LMA** in Chapter 6 are to be complied with as applicable.

7.3.2 The controls for propulsion arrangements are to be designed to allow for small accurate changes in propulsion speed which may typically be 0,2 knot/propeller speed ± 2 rpm.

7.3.3 The steering gear arrangements that provide a speed of rudder movement required in Vol 2, Pt 6, Ch 1,4.1 are to be recognised in the assessment of the ship's manoeuvring capability. The speed of rudder movement may require to be increased for ships intended for RAS operations that may typically be 35° to 30° opposite helm in 14 seconds with all the steering gear power actuating systems operating.

7.4 Communications, signals and navigational aids

7.4.1 Arrangements for ship internal communications during RAS operations are to be provided. The communication equipment and systems are to be arranged to permit safe and effective communications throughout the RAS operations to all parties identified in the engineering and safety justification and the design statement.

7.4.2 As a minimum, means of effective ship internal communications are to be provided in accordance with Table 7.7.1. In addition, means of communications are to be provided for all those personnel involved with operation of equipment or movement of stores during RAS operations. For example, communications should be provided from the RAS station to:

(a) The operators of fuel system valves, who need to be advised promptly of the completion of RAS operations so that the fuel system may be re-configured for normal running (unless valve operation is by remote control from the Master Filling Control Station).

Table 7.7.1 Internal communications

Position	Conning position	RAS observation position	RAS equipment control	Master filling control station	Notes
Conning position		+		+	
RAS station/VOA	+		+	+	*see* Note
RAS equipment control		+			
Master filling control station	+	+			
NOTE Each RAS station on the ship is to be capable of communication with the conning position, RAS equipment control and the master filling control station.					

(b) Those responsible for stowing the solid cargo who need to be appraised (quantity and type) of the stores en-route and the completion of RAS operations.

The communication equipment and systems provided are to take into account the design of the ship (e.g. the Master Filling Control Station may be located on the Bridge) and the intended method of operating the ship during RAS operations.

7.4.3 The design of internal communications equipment and systems is to provide sufficient redundancy such that in the event of a single equipment failure, RAS operations can proceed safely.

7.4.4 Ship to ship communication protocols and standards are to be specified and agreed between the Designer and Owner/Operator.

7.4.5 Arrangements are to be provided to allow the crew to accurately determine the distance between the ships during RAS operations (e.g. use a distance line) on a continuous basis. Guard rails or suitable alternatives are to be provided for the safety of personnel in exposed upper deck positions. The arrangements and operational procedures are to be such that the crew of neighbouring ships will not be exposed to RADHAZ.

7.4.6 Means of visual and aural communication between the ship conducting RAS operations is to be provided.

7.4.7 If distance lines and sound-powered communication equipment, as specified by the Owner/Operator, are to be passed between the ships that are to undertake RAS operations the following criteria are to be complied with:

(a) The positions of the communications equipment tie down/securing points and connections are to be agreed between the Designer and Owner/Operator and shown on the RAS general arrangement plan.

(b) Distance line securing points are to be clear of all RAS stations and positioned so the distance line is readily visible from the RAS officer's conning position. The exact locations for securing the distance lines are to be agreed between the Designer and Owner/Operator and shown on the RAS general arrangement plan.

7.4.8 The communication system requirements between receiving ship, delivery ship and helicopter during VERTREP operations are to be agreed between the Designer and Owner/Operator and be in accordance with Naval Authority requirements.

7.5 RAS operations

7.5.1 The power supplies to weapons systems are to be arranged to permit partial isolation in accordance with ship operation procedures (including RADHAZ) and orders relating to RAS operations.

7.5.2 Facilities are to be provided at each RAS station to permit electrical grounding of RAS equipment and stores. VERTREP stations are to be provided with facilities and equipment to permit the discharge of static electricity from the helicopter and/or its underslung cargo whilst airborne.

7.5.3 RAS systems are to be designed and installed such that they do not degrade from defined criteria (for equipment and the ship) stemming from susceptibility to magnetic interference sources that may include military activities. Systems are to comply with the technical requirements of IEC Publication 60533: *Electrical Installations in Ships, electromagnetic Compatibility*. Emission limits and immunity requirements are to be agreed by the Naval Authority where those specified in IEC 60533 are not appropriate for the ship type.

7.5.4 Facilities and equipment to undertake RAS operations in darkness are to be provided where the Naval Authority has agreed to such operations. Typically this will require provision of low intensity red lighting at each RAS station and on the routes to/from the RAS station to the stores and within the stores to allow safe operations in darkness. The arrangements are to be agreed between the Designer and Owner/ Operator and included in the design statement. Provision is also to be made for suitable low intensity lighting at control panels for operating RAS equipment.

■ *Section 8* RAS station requirements

8.1 General

8.1.1 Each RAS station is to incorporate the features described in 8.1.2 to 8.1.11. *See* 6.1 for RAS station location and equipment requirements.

8.1.2 The design of RAS stations is to recognise the need to minimise the risks to personnel during RAS operations. Wherever possible RAS stations are to be designed for RAS operations to be carried out with guard rails in position, where this is not practicable, alternative arrangements for the safety of personnel are to be provided. Use is to be made of non-slip paint and tripping hazards are to be eliminated wherever possible.

8.1.3 Clear areas are to be provided at each abeam RAS station. Clear areas in the vertical direction are to be contained within 30° forward and aft of the normal transverse from each RAS station. *See* Fig. 7.8.1.

8.1.4 The clear areas for VERTREP operations are to be agreed between the Designer and Owner/Operator. Reference is to be made to international standards for helicopter operations and the helicopter's capability requirements. The following are to be specified:

(a) Helicopter types.
(b) Underslung load earthing equipment/facilities.
(c) Range (size and weight) of cargo.
(d) Minimum clearance criteria.
(e) Lighting standards/requirements.
(f) Painting standards/requirements.
(g) Deck conductance for dissipation of static charge.

8.1.5 The layout of each RAS station is to provide sufficient accessibility for attendance, operation and maintenance of RAS equipment and systems in accordance with the manufacturer's recommendations.

8.1.6 A minimum distance of 3 m between any RAS station superstructure and the edge of the weatherdeck is to be provided at each RAS station.

8.1.7 Where space allows, provision is to be made for the rigging of a safety wire to which life lines can be attached. Note, such lines are to provided where the RAS station is designed for operations that require guard rails to struck, *see* 8.1.2.

8.1.8 Communications equipment and facilities are to be provided at each RAS station, *see* 7.1.

8.1.9 Oil spill containment arrangements are to be provided at each RAS station at which fuel and/or oil is taken on board. These arrangements are to cater for small spills that may occur during hose handling and connection operations. Small quantities of fuel or oil that may be spilt are to be contained and be capable of being discharged to a safe location and not overboard.

8.1.10 Where the Naval Authority has defined military requirements relating to radar cross-section, the increased cross section from exposed deck machinery and fittings is to be assessed with such equipment being recessed wherever practicable.

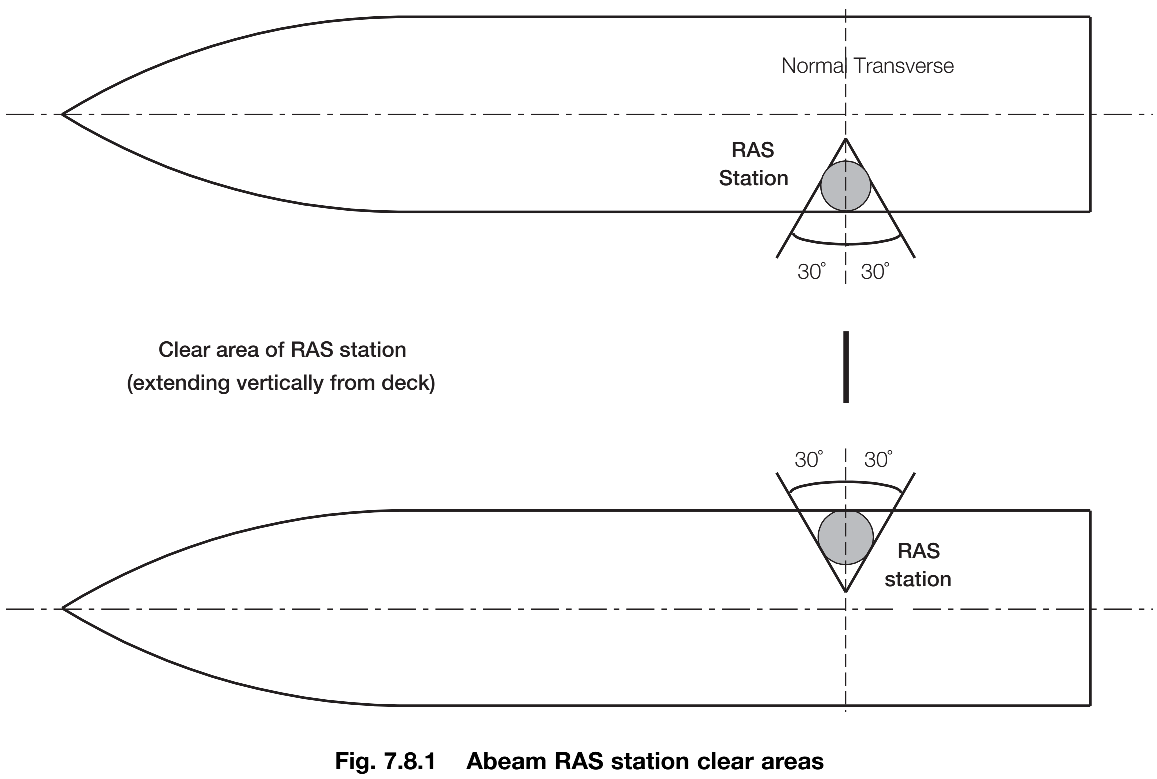


Fig. 7.8.1 Abeam RAS station clear areas

8.1.11 RAS high points for securing jackstays are to be located at least 3 m inboard of the deck edge and at the following recommended heights above deck level to ensure correct catenary of RAS equipment:

- 2,5 m for liquid transfer;
- 4,3 m for solids transfer.

8.2 RAS equipment control station

8.2.1 A dedicated RAS equipment control station is to be provided for all equipment at a RAS station.

8.2.2 Controls for RAS equipment that is to be operated sequentially as part of a system are to be grouped for control by a single operator wherever possible.

8.2.3 The RAS equipment control station is to be located so that the operator(s) has/have a clear view of all RAS equipment under their control.

8.2.4 The position of each RAS equipment control station is to be indicated on the general arrangement plan.

8.3 Emergency equipment

8.3.1 A RAS emergency equipment locker is to be provided and located near each RAS station. The locker is to contain all the emergency equipment and tools required to conduct emergency breakaway procedures for each RAS operation and equipment configuration.

8.3.2 The tools in the emergency equipment locker are to be in accordance with the equipment manufacturer's recommendations.

■ *Section 9* Transfer of liquids

9.1 General

9.1.1 Systems for the transfer of liquids are to be designed to minimise to as low as reasonably practicable the risks inherent with the RAS operational requirements for dealing with large quantities of fluids at high transfer rates.

9.1.2 The design of liquid transfer systems is to be such that it minimises danger to the ship, personnel and the environment.

9.1.3 Liquid transfer systems are to be designed to prevent over-pressurisation of transfer and filling lines and all associated storage tanks, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position. The design of filling systems is to consider maximum filling rates, dynamic pressure drops and maximum static pressures of the storage tanks.

9.1.4 The design and arrangements of liquid transfer systems is to permit blowing through/effective drainage of transfer hoses after RAS operations have been completed.

9.1.5 The arrangements for abeam transfer of oil fuel, lubricating oils, aviation fuel and fresh water are to be such that in the event of a single failure in a filling system, this does not prevent replenishment of these liquids, e.g. more than one RAS connection on each side of the ship and the ability to fill any tank from each RAS station from designated connections is to be provided.

9.1.6 Any storage tank overflow arrangements are to discharge to a safe position.

9.1.7 For requirements relating to water storage systems, see Vol 2, Pt 11, Ch 1.

9.1.8 For requirements relating to aviation fuel storage systems, *see* Vol 2, Pt 7, Ch 4.

9.1.9 For requirements relating to oil fuel storage systems, *see* Vol 2, Pt 7, Ch 3.

9.1.10 For requirements relating to air, overflow and sounding systems, *see* Vol 2, Pt 7, Ch 2,10.

9.1.11 For requirements relating to piping system design, *see* Vol 2, Pt 7, Ch 1.

9.1.12 For requirements relating to electromagnetic hazards, *see* Vol 2, Pt 1, Ch 2,4.18.

9.1.13 For requirements relating to control of static electricity, *see* Vol 2, Pt 10, Ch 1,1.12.

9.2 Filling connections and arrangements

9.2.1 Filling connections for liquid RAS operations are to be sited within the boundary of the RAS station. Each filling connection is to be provided with an accessible isolating valve located immediately under the deck with the valve controls led to a position above the weatherdeck sited near the filling connection. [Positioning the valve under the deck is to provide a clear area at the RAS station to minimise tripping hazards and radar reflective surfaces].

9.2.2 As far as practicable, separate filling connections are to be provided for each type of fluid that may be taken on board. To reduce the risk of inadvertent incorrect hose connection, the filling connections are to be of different types and separated as far as possible from each other for each type of liquid to be transferred.

9.2.3 A strainer unit, capable of being cleaned and a means of sampling incoming liquids, is to be provided at each filling connection.

9.2.4 Each filling connection is to be provided with a permanently attached notice identifying the fluid storage system(s) connected to the filling connection.

9.2.5 Filling connections and associated isolating valves are to be made from ductile materials. Where ships are required to operate in cold weather environments, materials of toughness greater than grade E are to be used.

9.2.6 Filling connections are to be designed to allow an emergency breakaway to take place safely, speedily and with a minimum effort from the crew.

9.2.7 Filling arrangements for flammable/hazardous liquids are to be designed to minimise the risk of static electricity build-up. The piping arrangements within storage tanks are to have outlet ends configured to reduce turbulence and foaming of the fuel. *See* Vol 2, Pt 10, Ch 1,1.12 for requirements for control of static electricity.

9.2.8 The control of filling operations for each system that can be replenished during RAS operations is to be capable of being carried out from a designated Master Filling Control Station. Designated Master Filling Control Stations are to be provided with:

(a) Effective communication equipment that permits communication with locations identified in the engineering and safety justification.
(b) Indication of tank high level and overflow alarms.
(c) Tank level/content indication.
(d) A clear visual means of ascertaining the valve configuration of each filling system.

9.2.9 The arrangements for replenishment of oil fuel and aviation fuel are to cater for water compensated tanks where these tanks are installed. *See* Vol 2, Pt 7, Ch 3,4.18.

9.2.10 The pipes for lubricating oil and fresh water transfer systems are to be permanent to minimise the risk of contamination.

9.2.11 Lubricating oil and fresh water filling arrangements are to be provided with a bulkhead filling connection positioned not less than 300 mm above the weatherdeck to minimise the risk of seawater ingress into the system.

9.2.12 The arrangements for transferring lubricating oils are to be such that permit the use of oil renovation systems whilst RAS operations are being carried out.

■ *Section 10*
Transfer of solids

10.1 General

10.1.1 Solid cargo may be transferred during RAS operations using abeam and/or VERTREP procedures.

10.1.2 The design of arrangements is to provide for rapid removal of cargo from the RAS station once received on board. The arrangements and equipment are to recognise the reception of large and/or heavy items of cargo and the number of crew required. A typical transfer rate is one pallet (1 m^3) every sixty seconds in good conditions.

10.1.3 The removal routes for cargo and stores are to be clearly marked and shown on handling plans.

10.1.4 Equipment intended for transfer of solids is to be capable of handling the maximum size and weight of solids identified in the design statement.

■ *Section 11*
Transfer of personnel

11.1 General

11.1.1 Arrangements for the transfer of personnel are to be in accordance with Naval Authority requirements.

11.1.2 In general only manually powered equipment is to be installed for the transfer of personnel.

11.1.3 The mechanical devices used in the tensioning of any rigging are to be of a proven safe design suitable for the purpose.

11.1.4 The design of arrangements for personnel is to provide sufficient space for the large numbers of crew normally required to operate the transfer equipment, typically twenty five personnel to tension the rig on a receiving ship.

■ *Section 12*
RAS equipment

12.1 General

12.1.1 The types of transfer that the ship is required to undertake are to be specified by the Owner/Operator and the selection of equipment is to be agreed between the Designer and Owner/Operator.

12.1.2 It is the responsibility of the Client to demonstrate the equipment is designed, manufactured, installed and tested in accordance with the applicable Rule requirements.

12.1.3 The selection of equipment is to address compatibility to provide for the correct rigging of equipment (blocks, shackle etc) for the loads imposed, e.g. it should not be possible to use a light jackstay shackle with a heavy jackstay rig.

12.2 Emergency breakaway

12.2.1 All RAS equipment and facilities are to be designed to permit the application of emergency breakaway procedures that should normally be complete within one minute of the commencement of initiation. Use may be made of quick release couplings and/or breakable couplings. Attention is to be given to the attachment of wires and ropes to winch drums and the selection of emergency breakaway equipment (wire cutters, axes, etc.).

12.3 Lifting devices

12.3.1 Winches are to incorporate safety features that permit safe RAS operations and cater for the unique loading conditions that may arise during RAS operations. The following features are to be considered:

(a) Service brake that permits quick and efficient engagement and disengagement by both automatic and manual means.
(b) Long term brake that permits long term locking of the winch drum having manual engagement and disengagement only.
(c) An overload facility that prevents the wire/rope being overstressed during RAS operations (e.g. when ships move or roll apart).
(d) Spooling system that ensures proper spooling of the wire onto the drum.
(e) Anti-slack device that maintains tension in the wire when the winch is operating under no load.

12.3.2 Cranes, derricks and booms for RAS operations are to comply with LR's *Code for Lifting Appliances in a Marine Environment*.

12.4 Hoses and fittings

12.4.1 Hoses for transferring liquids are to be in accordance with standards applicable to the intended application.

12.4.2 Where probe fuelling systems are part of the design, the following features are to be incorporated:

(a) Automatic latching mechanism with sleeve valve that opens on proper engagement and automatically closes on disengagement.
(b) Disengagement on application of a specified load.
(c) Swivel arm that keeps probe receiver aligned with the spanwire.
(d) Manual release lever.
(e) Quick release hook.
(f) Indication of incorrect probe engagement.

■ *Section 13* Testing and trials

13.1 General

13.1.1 Testing and trials are to be carried out to LR's satisfaction to demonstrate that systems and equipment operate and function as stated in the design statement.

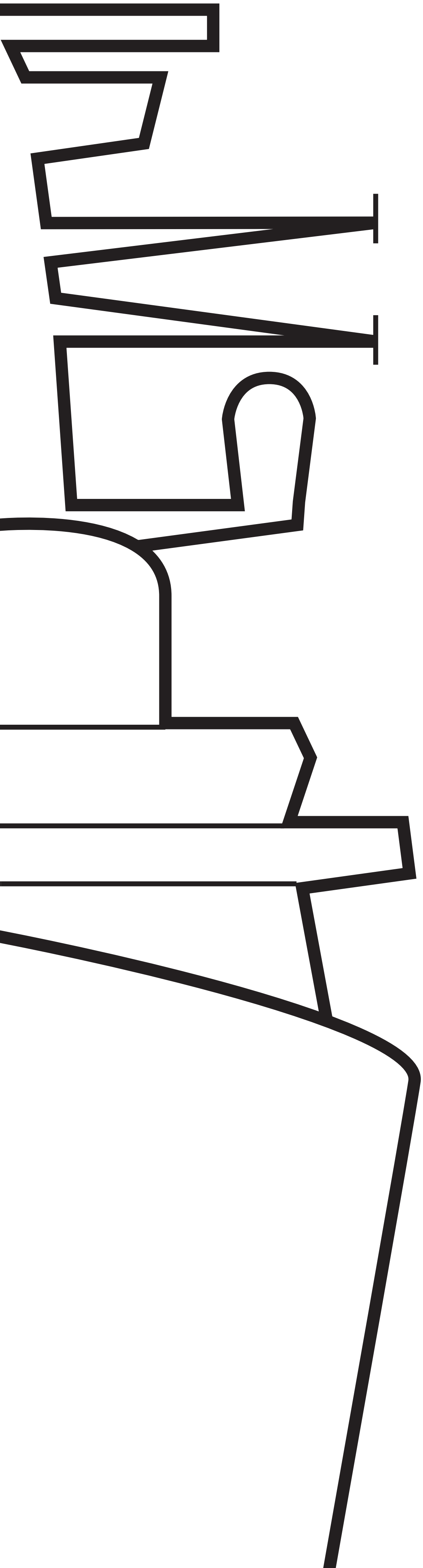
13.1.2 Testing and marking of equipment is to be in accordance with Chapter 9 of LR's *Code for Lifting Appliances in a Marine Environment* as applicable.

■ *Section 14* Survey through life

14.1 General

14.1.1 RAS systems are subject to survey through life to a schedule that has been agreed to by LR. All systems and equipment forming part of the RAS installation are to be identified and included in a list of surveyable items.

14.1.2 Survey and testing of systems and equipment are to be in accordance with Chapter 9 of LR's *Code for Lifting Appliances in a Marine Environment* as applicable.



Rules and Regulations for the Classification of Naval Ships

Volume 3 *Part 2*

Additional environmental and safety features

January 2005

Lloyd's Register

Chapter Contents

Volume 3, Part 2

Contents

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Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of noise and vibration levels on naval ships and are applied in addition to the other relevant requirements of the *Rules and Regulations for the Classification of Naval Ships* (here in after referred to as the Rules for Naval Ships).

1.1.2 These Rules apply to surface ships when engaged in peace-time mission profiles.

1.1.3 These Rules provide for two alternatives:

(a) A **Certificate of Compliance** which records that the ship has been designed and built to meet the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements during an Initial Survey, or

(b) A **Class Notation**, which in addition to the provisions of 1.1.3(a), requires periodic survey of the noise and vibration characteristics throughout the life of the ship.

1.1.4 For self-propelled ships below 200 tonnes static lightship displacement, higher noise and vibration levels will be permitted. Limits for these ships are identified within the text of these Rules.

1.1.5 These Rules recognise existing national and international standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters. Pre-survey reviews, inspections and measurements will be conducted, witnessed or assessed by Lloyd's Register (hereinafter referred to as 'LR') Surveyors.

1.1.6 These Rules present values of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the builders undertake calculations of noise and vibration so that any potential problem areas can be identified and control measures implemented.

1.1.7 Requirements additional to these in this Chapter may be imposed by the Naval Authority.

1.2 Definitions

1.2.1 **Crew and embarked personnel spaces** are defined as all areas intended for crew and embarked personnel use, and include the following:

(a) Accommodation spaces (e.g. cabins, corridors, offices, mess rooms, recreation rooms).

(b) Work spaces.

(c) Navigation spaces.

1.2.2 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.3 **Vibration level** is defined as the single amplitude peak value of deck structure vibration during a period of steady-state vibration, representative of maximum repetitive behaviour, in mm/s peak, over the frequency range 1 to 100 Hz.

1.3 Certificate of Compliance

1.3.1 The Certificate of Compliance provides ship operators with an objective assessment of a ship's noise and vibration levels in accommodation spaces at the time of the assessment.

1.3.2 The Certificate of Compliance is optional and if requested however, any ship can be assessed for compliance, using these requirements as a basis for the assessment.

1.3.3 To achieve the Certificate of Compliance, Sections 2 to 6 and 7.1 must be complied with.

1.3.4 The Certificate of Compliance will be issued after the Initial Survey, following satisfactory assessment of the measured data.

1.4 Class notations

1.4.1 The notations provide ship operators with an objective assessment of a ship's noise and vibration levels in accommodation spaces throughout its life.

1.4.2 The **CEPAC** (Crew and Embarked Personnel Accommodation Comfort) notation is optional.

1.4.3 For ships classed with LR which achieve the comfort standards specified in these Rules, the class notation **CEPAC** will be assigned. Following the **CEPAC** notation, numerals **1** or **2** will indicate the acceptance criteria to which the noise and vibration levels have been assessed.

1.4.4 The **CEPAC** notation indicates that the crew and embarked personnel accommodation and work areas meet the acceptance criteria.

1.4.5 To achieve and maintain any of the foregoing notations, Sections 2 to 7 must be complied with.

■ *Section 2* **Noise**

2.1 Maximum noise levels

2.1.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with ISO 1999.

2.1.2 For all stated noise levels the equivalent NR number is evaluated as the measured dB(A) level minus 5 dB(A).

2.1.3 Guidance on maximum acceptable sound pressure levels and noise exposure limits is given in IMO Resolution A.468(XII).

2.2 Crew and embarked personnel accommodation and work areas

2.2.1 When the ship is proceeding in its normal operating condition and in accordance with the provisions specified in 4.2, the noise levels specified in Table 1.2.1 and Table 1.2.2 are not to be exceeded.

Table 1.2.1 Accommodation – maximum noise levels, in dB(A)

	Ships greater than 200 tonnes lightship		Ships less than 200 tonnes lightship	
	Acceptance numeral		Acceptance numeral	
	1	2	1	2
Sleeping cabins, hospitals	50	60	55	60
Day cabins, Offices, conference rooms	55	65	60	65
Mess rooms	55	65	60	65
Open deck areas	65	75	70	75
Alleyways, changing rooms, bathrooms, lockers	70	80	75	80

Table 1.2.2 Work areas – maximum noise levels

Location	dB(A) level
Machinery space (continuously manned) e.g. stores	90
Machinery space (not continuously manned) e.g. pump, refrigeration, thruster or fan rooms	110
Workshops	85
Machinery control rooms	75
Wheelhouse, conning positions and operational control rooms	65
Bridge wings, additional limits:	
250 Hz octave band	68 (linear)
500 Hz octave band	63 (linear)
Radio rooms	60
Galleys and pantries:	
Equipment not working	70
Individual items at 1 m	80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge wings or forecastle	110

2.3 Acoustic insulation

2.3.1 Acoustic insulation of bulkheads and decks between crew spaces is to be in accordance with the requirements of IMO Resolution A.468(XII).

2.4 General alarm and crew and embarked personnel address systems

2.4.1 The general alarm and crew and embarked personnel address systems are to comply with 2.4.2 and 2.4.3 together with Vol 2, Pt 10, Ch 1 and 17.3.

2.4.2 During the noise measurement programme the general alarm and crew address systems are to be demonstrated by tests. These tests are to be undertaken under the sea trial conditions as described in 4.2.

2.4.3 When the ship is underway in normal conditions, the minimum sound pressure levels of the public address system for broadcasting emergency announcements are to comply with the following:

(a) In interior spaces:
- 75 dB(A), and
- at least 20 dB(A) above the speech interference level.

(b) In exterior spaces:
- 80 dB(A), and
- at least 15 dB(A) above the speech interference level.

NOTE

The speech interference level is defined as the arithmetic average of the sound pressure level of the ambient noise in the four octave bands: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Section 3 Vibration

3.1 Maximum vibration levels

3.1.1 Vibration limits are given in units of:

(a) peak acceleration (mm/s^2), single amplitude, in the range 1 to 5 Hz; and

(b) peak velocities (mm/s), single amplitude, in the range 5 to 100 Hz.

3.1.2 Measured vibration levels are to be assessed over the frequency range 1 to 100 Hz. The limits apply to each single frequency component of vertical, fore and aft and athwartship vibration which are to be assessed separately.

Table 1.3.1 Ships greater than 200 tonnes lightship. Accommodation – maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Sleeping cabins, hospitals	126	157	4	5
Day cabins, offices, conference rooms, mess rooms	157	189	5	6
Open deck areas	157	189	5	6
Alleyways, changing rooms, bathrooms, lockers	157	189	5	6

Table 1.3.2 Ships greater than 200 tonnes lightship. Work areas – maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Machinery spaces (continuously manned) and stores	157	189	5	6
Machinery spaces (not continuously manned) e.g. pump, refrigeration, thruster or fan rooms	157	189	5	6
Workshops and aircraft hangers	157	189	5	6
Machinery control rooms	126	157	4	5
Wheelhouse and conning, positions	126	157	4	5
Bridge wings	126	157	4	5
Command, control and communication compartments	157	189	5	6
Galleys and pantries	157	189	5	6
Normally unoccupied spaces	157	189	5	6

3.1.3 Crew and embarked personnel spaces are to be assessed with the ship proceeding in its normal condition and in accordance with the provisions set out in Section 4. The vibration levels specified in Tables 1.3.1, 1.3.2, 1.3.3 and 1.3.4 are not to be exceeded.

Table 1.3.3 Ships less than 200 tonnes lightship. Accommodation – maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Sleeping cabins, hospitals	157	189	4	6
Day cabins, offices, conference rooms, mess rooms	189	220	6	7
Open deck areas	189	220	6	7
Alleyways, changing rooms, bathrooms, lockers	189	220	6	7

Table 1.3.4 Ships less than 200 tonnes lightship. Work areas – maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Machinery spaces (continuously manned) and stores	189	220	6	7
Machinery spaces (not continuously manned) e.g. pump, refrigeration, thruster or fan rooms	189	220	6	7
Workshops and aircraft hangers	189	220	6	7
Machinery control rooms	157	189	5	6
Wheelhouse and conning, positions	157	189	5	6
Bridge wings	157	189	5	6
Command, control and communication compartments	189	220	6	7
Galleys and pantries	189	220	6	7
Normally unoccupied spaces	189	220	6	7

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation or by LR. In the former case, the measurements shall be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 4868.

4.2.2 The intended operating conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys will only be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are fully operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) Propulsion machinery operating profiles are to be submitted prior to the trials and a respective service condition agreed between the Owner and LR. Noise and vibration measurements will be taken at this service condition and the acceptance numeral assigned. In addition, noise and vibration measurements will be required at a condition where the power absorbed by the propeller(s) is not less than 85 per cent of the maximum continuous rating of the propulsion machinery. At this condition, the maximum noise and vibration levels relating to acceptance number 2 must not be exceeded.

(b) All propulsion and auxiliary machinery, including HVAC systems, are to be running in their normal seagoing mode during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary.

(c) Measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship.

(d) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code.

(e) The ship is to be at a displacement and trim corresponding to the normal operating condition.

(f) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.

(g) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration levels are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.

(h) Care is needed to ensure that external sources of noise, due to aircraft for example, do not influence the noise measurement results.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:

(a) Measurement locations, indicated on a general arrangement of the ship.

(b) The ship's outfit condition during survey.

(c) The machinery operating condition, including HVAC system, during survey.

(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution A.468. Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 651, Type 1 or 2. Subject to demonstration, equivalent standards are acceptable.

4.3.2 Where the measured noise exceeds the relevant criteria by 3 dB(A), or contains subjectively annoying low frequency noise, or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that assessment represents the overall noise environment on board the ship. At least 50 percent of the sleeping accommodation areas are to be surveyed. Distribution of the measurement locations is to be agreed by LR.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 4868.

4.5.2 Measurements are to be made with an electronic system capable of providing vibration frequency spectra in the range 1 to 100 Hz.

4.5.3 Vibration levels are to be given in maximum repetitive peak values measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as mess rooms, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

■ *Section 5* Survey reporting

5.1 General

5.1.1 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.2 The survey report shall be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923, and is to include:

(a) The results of public address and general alarm system testing, in addition to the acoustic insulation testing.
(b) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.
(c) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The NR number is also to be given where octave band analyses have been conducted.
(d) Ship and machinery details.
(e) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(f) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).
(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.
(b) The maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.
(c) Ship and machinery details.
(d) Trial details:
- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial number), including frequency analysis parameters (e.g. resolution, averaging time and window function).
(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Excessive noise and vibration

6.1 Noise excesses

6.1.1 Noise levels greater than those specified in these Rules may be considered. Not more than 20 percent of the accommodation cabins are to exceed the relevant noise criteria by more than 3 dB(A)

6.2 Vibration excesses

6.2.1 Vibration levels greater than those specified in these Rules may be considered. Not more than 20 per cent of all accommodation cabins are to exceed the relevant vibration criteria by more than 0,3 mm/s.

Section 7
Survey requirements

7.1 Initial Survey

7.1.1 The Initial Survey shall comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

7.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

7.2 Periodical Survey (first 6 years)

7.2.1 An Annual Survey is to be held between 9 and 15 months after the completion of the Initial Survey. Measurements of noise and vibration will be required at a minimum of 25 per cent of the locations specified for the Initial Survey. The locations are to be submitted to LR for agreement, prior to commencement of the Annual Survey.

7.2.2 An Intermediate Survey is to be held within three months before or after the third anniversary of completion of the Initial Survey. The percentage of measurements required is to be as specified in 7.2.1.

7.2.3 If the limiting criteria as described in 6.1 and 6.2 are exceeded and the cause of the exceedance cannot be rectified at the time of the survey, then a Renewal Survey may be required.

7.3 Periodical Surveys (subsequent years)

7.3.1 A Renewal Survey is to be held at six-yearly intervals, the first one six years from the completion of the Initial Survey. The measurements required shall be the same as those required for the Initial Survey.

7.3.2 Following each Renewal Survey, an Intermediate Survey is to be held between the second and third subsequent years. The percentage of measurements required is to be as specified in 7.2.1.

7.4 Surveys following modifications

7.4.1 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

Section 8
Referenced standards

8.1 Noise

8.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels*.
- ISO 1999, *Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment*.
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements*; Part 1: *Airborne sound insulation*.
- IMO Resolution A.468(XII), *Code on noise levels on board ship*.
- IEC Publication 651, *Sound level meters*.
- ISO 140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements*; Part 4: *Field measurements of airborne sound insulation between rooms*.

8.2 Vibration

8.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954, *Mechanical vibration and shock – Guidelines for the overall evaluation of vibration in merchant ships*.
- ISO 4868, *Code for the measurement and reporting of local vibration data of ship structures and equipment*.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter contains requirements for the control of operational pollution on naval ships.

1.1.2 Compliance with this Chapter is optional. A ship meeting the requirements of this Chapter will be eligible for an appropriate class notation, which will be recorded in the *Register Book*.

1.1.3 Additional requirements may be imposed by the Naval Authority. If specifically requested, Lloyd's Register (hereinafter referred to as 'LR') may provide suitable certification or statement of compliance.

1.1.4 LR is to be advised of any matter that relates to the environmental performance of the ship that would affect the assignment of the **EP** class notation. The requirements of the Rules for the **POL** notation included in Vol 3, Pt 3, Ch 6 are to be complied with as part of demonstrating compliance with these Rules.

1.2 EP class notation

1.2.1 Section 2 states the minimum requirements to be met for assignment of the **EP** notation.

1.2.2 Section 3 contains additional requirements. Ships complying with these requirements will be eligible for one or more of the following associated supplementary characters, as applicable:
A Anti-fouling coatings.
B Ballast water management.
F Protected fuel tanks.
G Grey water.
N Oxides of nitrogen (NO_x) exhaust emissions.
R Refrigeration systems.
S Oxides of sulphur (SO_x) exhaust emissions.
O Oily bilge water.

1.3 Information to be submitted

1.3.1 The following are to be submitted:
(a) One copy of all plans and information listed in 1.3.4.
(b) Two copies of the Operational Procedures.
(c) One copy of every Certificate.
(d) One copy of any information relating to the environmental performance of the ship, which may influence the assignment of the **EP** notation.

1.3.2 Certificates:
(a) MARPOL certificates or certification, as applicable.
(b) Interim Engine International Air Pollution Prevention (EIAPP) Certificate or statement of compliance with the NO_x emission requirements of MARPOL Annex VI.
(c) Incinerator certificate or statement of compliance with the requirements of MARPOL, Annex IV, Regulation 16.
(d) Sewage system and, where fitted, sewage treatment system statement of compliance with the requirements of USCG 33 CFR 159 and/or MARPOL 73/78 Annex IV.

1.3.3 Operational procedures:
(a) NO_x emission control, as applicable.
(b) Oil fuel management for the control of SO_x emissions.
(c) Refrigerant management.
(d) Oil pollution prevention measures.
(e) Garbage management.
(f) Sewage treatment and discharge control.
(g) Precautionary measures to minimize the transfer of non-nature organisms in ballast water.
(h) Ballast water management.

1.3.4 Information and plans:
(a) Details of engine type, rated power and intended use for all installed engines.
(b) Details of NO_x control arrangements, as applicable. Arrangements of permanently installed refrigeration systems (including those used for chilled water, air conditioning, domestic store rooms and chiller units).
(c) Capacity of refrigeration system.
(d) Details of intended refrigerant(s).
(e) Details of fire-extinguishing media to be used in fixed fire-fighting systems and portable extinguishers.
(f) Bilge holding, waste oil and sludge tank capacities and piping arrangements.
(g) Arrangements of oil loading and discharge connections together with associated drip trays and drainage systems.
(h) Oil fuel storage, settling and service tank high level alarms/overflow systems.
(j) Details of sewage treatment and handling systems.
(k) Capacity of sewage holding and/or treatment system.
(l) Maximum numbers of crew and embarked personnel.
(m) Details of incinerator arrangements, as applicable, associated piping systems, control and monitoring equipment.
(n) Hull coating system and leaching rate.
(o) Ballast water treatment arrangements, as applicable (for supplementary **B** character only).
(p) Any information relating to the environmental performance of the ship, which may influence the assignment of the **EP** notation.

(q) Arrangements of protected oil tanks (for supplementary **F** character only).
(r) Details of grey water treatment plant and effluent quality (for supplementary **G** character only).

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved arrangements and procedures is proposed, appropriate details are to be submitted for approval.

1.5 In-service records

1.5.1 Records demonstrating the effective implementation of the operational procedures specified in 1.3.3, as applicable, are to be maintained.

1.5.2 These records are to be kept on board for a minimum period of three years, in a readily accessible form, and are to be available for inspection by LR Surveyors, as required.

■ *Section 2* Environmental Protection (EP) class notation

2.1 General

2.1.1 It is a prerequisite for assignment of the **EP** notation that the ship is classed with LR and demonstrates compliance with all relevant Annexes of MARPOL.

2.1.2 Where a ship, by virtue of its gross tonnage, would not be required by the MARPOL Convention to have MARPOL Certification, the following are to be maintained:
(a) An Oil Record Book in accordance with MARPOL Annex I.
(b) A garbage management plan and record book in accordance with MARPOL Annex V.

2.1.3 High speed craft, as defined below, will be the subject of special consideration.
A high speed craft is a craft capable of maximum speed, V, not less than:

V = 7,19 $\nabla^{1/6}$ knots

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline. The design waterline is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2 Oxides of nitrogen (NO_x)

2.2.1 These requirements apply to all installed diesel engines with an individual output power greater than 130 kW, other than those used solely for emergency purposes. There are no specific requirements relating to NO_x emissions from boilers, incinerators or gas turbine installations.

2.2.2 All engines falling within the scope of MARPOL Annex VI, Regulation 13 are to comply with its provisions and be certified accordingly.

2.2.3 Engines over 130 kW, other than those used solely for emergency purposes, not falling under the requirements of MARPOL Annex VI, Regulation 13, are also to comply with the applicable emission values detailed in paragraph 3(a) of that Regulation. The test procedure and measurement method are to be in accordance with either the Simplified Measurement Method or Direct Measurement and Monitoring Method as detailed in Chapter 6 of the NO_x Technical Code.

2.2.4 Where the NO_x emission limits specified in MARPOL, Annex VI, Regulation 13 are exceeded, an emission reduction plan to reduce emission levels to those specified in the aforementioned Regulation are to be developed and agreed with LR.

2.2.5 Equipment and systems used to control NO_x emission levels are to:
(a) be arranged so that failure will not prevent continued safe operation of the engine;
(b) be operated in accordance with manufacturer's instructions;
(c) be designed, constructed and installed to ensure structure integrity and freedom from significant vibration;
(d) be designed to include adequate hatches for inspection and maintenance purposes; and
(e) be instrumented to record operation. Records of operation and the degree of control are to be maintained.

Alternative control arrangements will be given special consideration.

2.2.6 Procedures covering the use and maintenance of the equipment and systems specified in 2.2.5 are to be established and effectively implemented. Records are to be maintained which demonstrate the operation of the equipment and systems and the resultant level of NO_x emissions to the atmosphere.

2.3 Oxides of sulphur (SO_x)

2.3.1 Emission of SO_x is to be controlled by limiting the sulphur content of oil fuels used on board.

2.3.2 The maximum sulphur content of oil fuel to be used on board will be dependent upon area of operation and bunkering ports. The maximum permissible fuel sulphur content will be ship-specific and will be specified by LR, based on fuel availability. In all cases, this will not exceed 3,5 per cent.

2.3.3 Where the grade of fuel normally used cannot be obtained with the appropriate fuel sulphur level, then a better grade of fuel meeting this requirement will need to be purchased.

2.3.4 An oil fuel management system is to detail the maximum sulphur content to be specified when ordering oil fuels and the means adopted to verify that the sulphur content of oil fuels supplied meets that requirement. This management system is to include the practices to be adopted to ensure that appropriate low sulphur oil fuels are used when the ship is within IMO designated 'SO_x Emission Control Areas', as applicable.

2.3.5 Where testing to determine the sulphur content of fuel received on board is to be carried out, a representative sample is to be drawn at the time of delivery from the ship's bunker manifold using the manual or automatic sampling methods defined in ISO 3170 or 3171, or their national respective equivalents. Fuel sulphur content is to be subsequently determined using the laboratory test method ISO 8754 or an equivalent National Standard based on ISO 8754.

2.4 Refrigeration systems

2.4.1 These requirements apply to refrigeration, chilled water and air conditioning installations on all naval ships. These requirements do not apply to the domestic stand-alone refrigerators used in galleys, pantries, bars and crew accommodation.

2.4.2 The use of chlorofluorocarbons (CFC) in refrigeration or air conditioning installations is prohibited. However installations containing hydrochlorofluorocarbons (HCFC) are permitted until 1 January 2020.

2.4.3 Systems are to be arranged with suitable means of isolation so that maintenance, servicing or repair work may be undertaken without releasing the refrigerant charge into the atmosphere. Unavoidable minimal releases are acceptable when using recovery units.

2.4.4 For the purposes of refrigerant recovery, the compressors are to be capable of evacuating a system charge into a liquid receiver. Additionally, recovery units are to be provided to evacuate a system either into the existing liquid receiver or into cylinders dedicated for this purpose. The number of cylinders is to be sufficient to contain the complete charge between points of isolation in the system.

2.4.5 Where different refrigerants are in use they are not to be mixed during evacuation of systems.

2.4.6 Refrigerant leakage is to be minimised by leak prevention and periodic leak detection procedures. The annual refrigerant leakage rate for each system shall be less than 10 per cent of its total charge.

2.4.7 A leak detection system appropriate to the applicable refrigerant is to be provided to monitor continuously the spaces into which the refrigerant could leak. An alarm is to be given in a permanently manned location when the concentration of refrigerant in the space exceeds a predetermined limit (25 ppm for ammonia; 300 ppm for halogenated fluorocarbons). Remedial measures to repair the leakage are to be implemented as soon as practicable after an alarm is activated.

2.4.8 Procedures detailing the means to be adopted to control the loss, leakage, venting and disposal of refrigerants are to be established and implemented effectively.

2.4.9 Refrigerant inventory and log book records of the following are to be maintained covering:
(a) Refrigerant added to each system.
(b) Refrigerant leaks, including remedial actions.
(c) Refrigerant recovered and where stored.
(d) Refrigerant consumption.
(e) Refrigerant disposal.

2.5 Fire-fighting systems

2.5.1 The use of halon or halo-carbons as the fire-extinguishing medium in fixed fire-fighting systems or extinguishers is not permitted.

2.6 Oil pollution prevention

2.6.1 All ships are to comply with the requirements of 2.6.2 to 2.6.11.

2.6.2 Drainage from machinery space bilges may be discharged to sea in accordance with the requirements of MARPOL 73/78, Annex 1.

2.6.3 The oil in water content of the water discharged is to be less than 15 ppm. Oily bilge water is to be discharged through approved oil filtering equipment and a 15 ppm alarm combined with a device for automatically stopping any discharge to sea when the oil content in the discharge exceeds 15 ppm. Full records of all discharges are to be kept.

2.6.4 Oil fuel, lubricating oil and other oil loading or discharge connections on deck are to be fitted with drip trays. Drip trays are to be fitted with closed drainage systems.

2.6.5 Oil fuel storage, settling and service tanks are to be fitted with high level alarms and/or acceptable overflow systems.

2.6.6 Leakages and waste oil from machinery and equipment are to be collected in a dedicated waste oil tank prior to disposal ashore or incineration. This waste oil tank is to be separate from the sludge tank specified in MARPOL Annex I, Regulation 17. The volume of the waste oil tank is to be of sufficient capacity to hold a complete lubricating oil charge from the largest engine used for propulsion or electrical generating purposes.

2.6.7 For those ships which only operate on distillate fuel, the waste oil and sludge tanks may be combined to form a single tank. Where such a combined tank is fitted, the total capacity is to be equal to or greater than the aggregated total of the required individual tank capacities.

2.6.8 The bilge holding tank, the waste oil tank and the sludge tank are to be arranged to facilitate the periodic removal of accumulated sediments and other material.

2.6.9 Discharge piping systems to deck from the bilge holding tank, and the waste oil tank, are to be separate from the oil fuel loading and transfer systems. The bilge holding tank and waste oil tank piping systems are to be terminated with the standard discharge connections specified in MARPOL Annex I, Regulation 19. The sludge tank may be discharged through the same piping system as the waste oil tank.

2.6.10 Means are to be provided for the collection and recovery of any oil spilled on decks.

2.6.11 Procedures covering the handling of all oils and oily wastes are to be established and implemented effectively. As a minimum, these are to cover:

(a) loading, storage and transfer of oil fuels, lubricants, hydraulic oil, thermal heating oil and drummed oil products;
(b) storage, transfer, discharge and disposal of oily mixtures contained in the ship's sludge, bilge holding and waste oil tanks and machinery space bilges; and
(c) recovery of any oil spilled on decks.

2.7 Garbage handling and disposal

2.7.1 Procedures covering garbage management are to be established and effectively implemented. As a minimum, these procedures are to include:

(a) identification of the sources of garbage;
(b) means of minimizing garbage production;
(c) procedures for the safe and hygienic collection, segregation, storing, processing and disposal of garbage, including the use of the equipment (compactors, comminuters, incinerators or other devices) on board. These procedures are to cover all garbage generated during the normal operation of the ship. The disposal of the following materials is to be specifically covered:
    - Waste oil.
    - Paint and painting materials.
    - Medical wastes.
    - Large metal objects such as oil drums and machinery components.
    - Ropes: metal, synthetic or natural fibre.
    - Rust/scale debris.
    - Ballast tank sediments.
    - Equipment containing refrigerants.

2.7.2 Where fitted, incinerators are to be designed and constructed in accordance with the requirements of IMO Resolution MEPC 76(40). A certificate of compliance is to be provided.

2.7.3 Where incineration is to be carried out, procedures are to be developed and implemented covering:

(a) operation in accordance with the requirements of MARPOL Annex VI, Regulation 16; and
(b) prevention of incineration within areas where incineration is prohibited by the Coastal State Administration.

2.8 Sewage treatment

2.8.1 The capacity of the sewage treatment system, where fitted, is to be sufficient for the maximum number of persons on board. Where 'black water' only is treated, the minimum capacity is to be 115 litres/person/day for a conventional flushing system or 15 litres/person/day for a vacuum system. Where both 'black water' and 'grey water' are treated, a minimum additional allowance of 135 litres/person/day is to be made. Alternative minimum capacities will be specially considered on an individual basis where there is evidence from similar naval ships and the Naval Authority is in agreement.

2.8.2 Procedures for the operation of a sewage treatment system, including the certification of performance, are to be established and effectively implemented. Records are to be maintained of maintenance, repair, remedial work and disinfectant closing rates.

2.8.3 The manufacturer's restriction on materials, which may be disposed of through the sewage treatment system are to be clearly displayed at each input point.

2.8.4 The disinfectant dosing points of the sewage treatment system are to be readily accessible. Ready access is also to be provided for the taking of samples.

2.8.5 As an alternative to treatment, sewage may be retained onboard. The sewage holding tank is to be of adequate capacity taking into account the operation of the ship, the number of persons on board and other relevant factors such as the time the ship is anticipated to operate within literal waters. The tank is to be fitted with a visual contents gauge and a high level alarm.

2.8.6 Records are to be maintained detailing discharges from the holding tank. These should include:

(a) the date, location and quantity of sewage discharged from the holding tank either ashore or at sea;
(b) distance from land and ship's speed, when sewage is discharged to sea.

2.8.7 Ventilation pipes from the sewage system are to be independent of other vent systems.

2.9 Hull anti-fouling systems

2.9.1 Prior to 1 January 2003, the application of anti-fouling systems containing tributyltin (TBT) is acceptable provided that the leaching rate does not exceed 4 $\mu g/cm^2/day$, as determined by ASTM Method 5108-90.

2.9.2 From 1 January 2003, the application of anti-fouling systems containing TBT is prohibited. Ships to which TBT-based anti-fouling systems have been applied prior to this date will be accepted until 1 January 2008, provided the TBT leaching rate does not exceed 4 μg/cm^2/day, as determined by ASTM Method 5108-90.

2.10 Ballast water

2.10.1 All ships carrying ballast water are to implement precautionary measures to minimize the translocation of non-native organisms in their ballast water unless it can be demonstrated that the risk of translocation of non-native organisms in their ballast water and sediments are minimal.

2.10.2 As a minimum, precautionary measures to minimize the translocation of non-native organisms are to include:

(a) minimizing the uptake of aquatic organisms, pathogens and sediments during ballasting, by limiting or minimising ballasting in situations where the numbers of aquatic organisms are likely to be increased locally. For example:
- in darkness, when bottom-dwelling organisms may rise up the water column;
- in very shallow water;
- where propellers may stir up sediment;
- in areas specified by the Port State for avoidance or restriction of ballasting;

(b) monitoring of sediment build up and, where practicable, routine cleaning of ballast tanks to remove sediments.

(c) planning uptake and discharge of ballast water such that where ballast needs to be taken on and discharged in the same port, discharge of ballast loaded in another port is to be avoided, where practicable.

■ *Section 3* Supplementary characters

3.1 Hull anti-fouling systems – A character

3.1.1 For assignment of the **A** character, the anti-fouling system applied to the ship's hull is to be non-biocidal.

3.2 Ballast water management - B character

3.2.1 Where ballast water management is undertaken, for assignment of the **B** character, a ballast water management plan approved by the Naval Authority, is to be in place and implemented effectively.

3.2.2 The ballast water management plan is to take account of the safety considerations detailed in IMO Resolution A.868(20).

3.3 Protected fuel tanks – F character

3.3.1 For assignment of the **F** character, oil fuel and lubricating oil tanks are to be located in a protected location away from the ship's side or bottom shell plating. This requirement does not apply to main engine lubricating oil drain tanks.

3.3.2 Oil tanks are to be located as follows:

oil tanks with a capacity of less than 1000 m^3 are to be located at least 0,76 m from the ship's side or bottom plating; and

oil tanks with a capacity of 1000 m^3 and over are to be located at least 1,5 m from the ship's side or bottom plating.

3.3.3 Arrangements providing equivalent protection will be given special consideration.

3.3.4 Suction wells may protrude below oil fuel tanks provided they are as small as possible and the distance between the tank bottom and the ship's bottom shell plating is not reduced by more than 50 per cent.

3.4 Grey water – G character

3.4.1 Where plant for the treatment of grey water is installed and utilized effectively, the **G** character will be assigned, subject to the plant effluent meeting the standards specified in 3.4.2 or 3.4.3, as applicable.

3.4.2 Where it is not intended that the effluent is recycled or re-used for any purpose, the effluent of the grey water treatment plant is to meet the following standards:

(a) Faecal coliforms:
Content is not to exceed 250/100 ml M.P.N. (most probable number) as determined by a multiple tube fermentation analysis or an equivalent procedure.

(b) Suspended solids:
Where the equipment is tested onshore, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed 50 mg/l.
Where the equipment is tested onboard the ship, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed the suspended solids content of the ambient water used onboard plus 100 mg/l.

(c) Biochemical Oxygen Demand (BOD_5):
The geometric mean of a 5-day Biochemical Oxygen Demand is not to exceed 50 mg/l.
When testing onboard the ship, if insufficient time is available for obtaining a number of samples over a period of days, a BOD_5 not exceeding 100 mg/l on a single sample will be accepted providing that suspended solids are within the value stated above.

3.4.3 Where it is intended that the effluent of the grey water treatment plant is to be re-used or recycled for any purpose, the effluent is to meet the potable water quality standards of Naval Authority.

3.5 Oily bilge water – O character

3.5.1 For assignment of the O character, all drainage from machinery space bilges is to be discharged ashore, except under exceptional circumstances.

3.5.2 Alternatively, discharge to sea is permitted where it can be demonstrated that the oil-in-water content of the water discharged is less than 5 ppm.

3.5.3 Full records of all discharges are to be kept.

3.6 Oxides of nitrogen (NO_x) – N character

3.6.1 For assignment of the **N** character, the total weighted value of NO_x emissions from all installed diesel engines defined within 2.2.1 is not to exceed 80 per cent of the total weighted NO_x emission limits specified in MARPOL Annex VI, Regulation 13.

3.6.2 The total weighted emission value for the ship (*WV*) is to be calculated as follows:

$$WV_{[ship]} = \frac{WAEV_{[cert]}}{WAEV_{[IMO]}}$$

where

$$WAEV_{[cert]} = \frac{\sum_{n=1}^{n} (NO_{x[cert]}.P)}{\sum_{n=1}^{n} (P)}$$

$$WAEV_{[IMO]} = \frac{\sum_{n=1}^{n} (NO_{x[IMO]}.P)}{\sum_{n=1}^{n} (P)}$$

n = the number of individual engines on board the ship
P = the rated power, in kW, of each individual installed engine
$NO_{x[cert]}$ = the certified NO_x emission value, in g/kWh, for each individual engine
$NO_{x[IMO]}$ = the NO_x emission limit value, in g/kWh, of each individual engine as specified in Regulation 13 of Annex VI to MARPOL.

3.6.3 The **N** character will be assigned when:

$$\frac{WAEV_{[cert]}}{WAEV_{[IMO]}} \leq 0{,}8$$

3.6.4 The test procedure and measurement method are to be in accordance with either the Simplified Measurement Method or Direct Measurement and Monitoring Method given in Chapter 6 of the IMO NO_x Technical Code.

3.6.5 Systems and equipment used to control the NO_x emissions are to comply with the requirements specified in 2.2.5.

3.6.6 In the case where the individual engines are 'family' or 'group' engines, as defined in the NO_x Technical Code, the certified emission value may be based on that of the parent engine.

3.7 Refrigeration systems – R character

3.7.1 For assignment of the **R** character, in addition to compliance with the requirements of 2.4, all refrigerants used onboard are to have an Ozone Depleting Potential (ODP) rating of zero and a Global Warming Potential (GWP) of less than 1950, based on a 100-year time horizon.

3.8 Oxides of sulphur (SO_x) – S character

3.8.1 For assignment of the **S** character, all gas oil used onboard is to have a sulphur content of less than 0,20 per cent m/m. All heavy fuel oil is to have a sulphur content of less than 1 per cent m/m.

3.8.2 The sampling, fuel sulphur analysis methods and verification requirements stipulated in 2.3.4 and 2.3.5 are to be complied with.

■ *Section 4* **Survey requirements**

4.1 Initial Survey and Audit

4.1.1 Following satisfactory review of the plans and other information submitted (*see* 1.3), an EP Initial Survey is to be undertaken for ships under construction or in service.

4.1.2 At the EP Initial Survey, the Surveyor is to be satisfied that the requirements of these Rules, including those relating to any requested supplementary characters, are complied with. The Surveyor is to verify that the hull and machinery arrangements are in accordance with the approved documentation. The installed equipment, together with associated control and alarm systems, is to be demonstrated under working conditions.

4.1.3 Following the successful completion of the Initial Survey, the **EP** notation may be provisionally assigned to a ship. The provisional **EP** notation will be valid, in the first instance, for a period not exceeding 6 months. During this period, an audit of the procedures as required by these Rules is to be undertaken. This audit is to be performed after the procedures have been fully implemented, subjected to internal audit and have generated at least 3 months of records under in-service conditions.

4.1.4 Audits are to confirm by direct observation, examination of internal audit reports and scrutiny of records that each of the procedures have been implemented effectively over the preceding period. It is also to be verified that:
(a) the required resources and equipment have been provided; and
(b) the ship's staff are aware of their duties and responsibilities, and can perform the assigned tasks.

4.1.5 The full **EP** notation will be assigned following satisfactory completion of the audit.

4.2 Periodical Surveys and Audits

4.2.1 EP Annual Surveys are to be held on all ships to which the **EP** notation applies within three months of each anniversary for assignment of the full **EP** notation.

4.2.2 At the EP Annual Survey, the Surveyor is to be satisfied that the arrangements and equipment comply with these Rules. As far as possible, the installed equipment, together with associated control and alarm systems, are to be demonstrated under working conditions. Additionally:

(a) where changes to arrangements or equipment fitted to meet the requirements of these Rules have been made, it is to be verified that these changes are in accordance with approved documentation; and
(b) records for the preceding 12 months are to be reviewed.

4.2.3 EP Audits are to be held at either the second or third anniversaries of the completion of the Initial or Renewal Surveys. EP Audits are to be undertaken in accordance with the requirements given in 4.1.4.

4.2.4 All ships to which the **EP** notation applies are also to be subjected to EP Renewal Surveys in accordance with the requirements given in 4.2.5. These surveys become due at five-yearly intervals, the first being five years from the completion of the Initial Survey.

4.2.5 At the EP Renewal Survey, in addition to the survey requirements in 4.2.2:

(a) continued compliance with the NO_x emission limits specified in 2.2.2 or 2.2.3 is to be demonstrated; and
(b) a satisfactory audit is to be undertaken in accordance with the requirements given in 4.1.4.

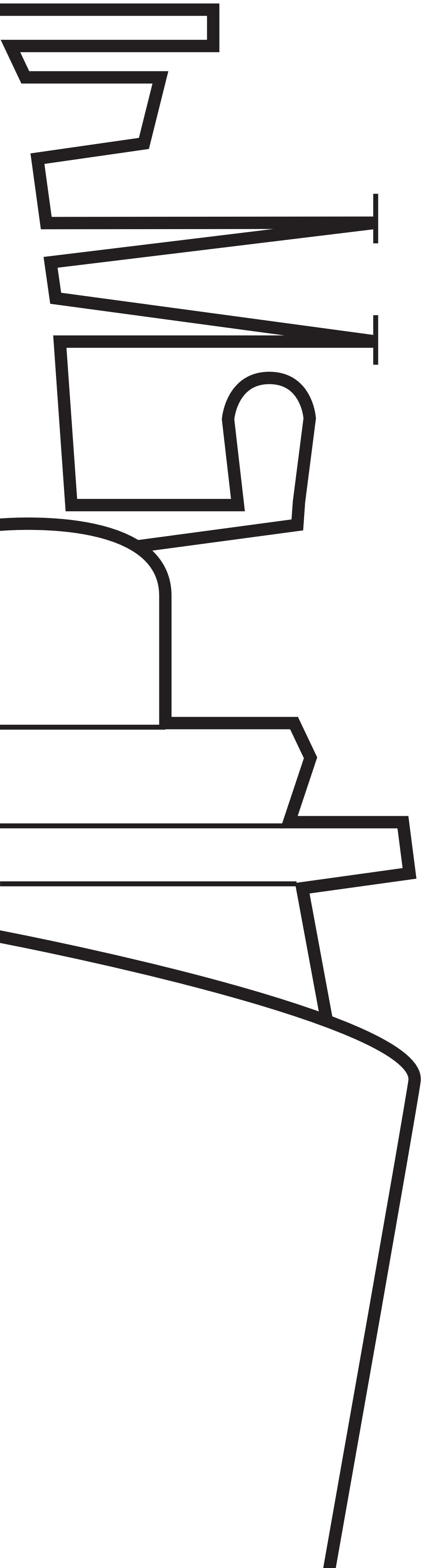
4.3 Change of Naval Authority

4.3.1 Where the Naval Authority changes, the **EP** notation will be suspended.

4.3.2 The new Naval Authority may adopt the previously approved procedures as required by these Rules or may compile new procedures which would need to be submitted for approval.

4.3.3 Following implementation of the approved procedures, an audit, in accordance with the requirements in 4.1.3 and 4.1.4, is to be undertaken.

4.3.4 The **EP** notation will be re-assigned following successful completion of the audit provided that the general requirements given in 2.1.1 are complied with.



Rules and Regulations for the Classification of Naval Ships

Volume 3 *Part 3*

Safety equipment and arrangements

January 2005

Lloyd's Register

Chapter Contents

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Section 1 **Scope**

1.1 Application

1.1.1 The Chapters in this Part of the Rules define the requirements for the design and service life of safety equipment and arrangements. The Chapters are provided for the purpose of assessing that the levels of safety (of crew and embarked personnel) and pollution prevention on board a naval ship are to a standard which is acceptable to the Naval Authority and Lloyd's Register (hereinafter referred to as LR). The Rules provide a standard that can be considered to be as far as reasonably practicable in accord with the applicable IMO International Conventions but take due cognisance of military application. They also provide a methodology for assessing the suitability of designs that deviate from generally accepted practice.

1.1.2 In general a Class Notation contained in this Part of the Rules will only be assigned where the vessel has been assigned an **LMC** notation (*see* Vol. 1, Pt 1, Ch 2). However where a Certificate of Compliance is sought it may be demonstrated that an equivalent provision of equipment and arrangements is provided on board the vessel. In addition, the equipment and arrangements are also to be in compliance with the applicable sections of Volumes 1 and 2 of these Rules. Other acceptable standards such as Naval Defence Standards may be used subject to satisfactory review by LR.

1.1.3 For the purpose of the application of this Part of the Rules, 'in accord with' and 'equivalence/equivalent' are understood as: Acceptance of any fitting, material, apparatus, arrangement or type thereof required by these Rules if LR is satisfied that such fitting, material, apparatus or arrangement, or type thereof, meets the Objectives specified in these Rules.

1.1.4 Attention is also to be given to any relevant requirements of the Naval Authority.

1.1.5 These Rules are applicable only to ships carrying crew and embarked personnel. The carriage of passengers is considered novel for most naval ships and will generally only be undertaken during emergency situations or where specially agreed by the navy. The carriage of passengers is therefore outside the scope of these Rules. Special consideration will be given to arrangements where passengers are carried and will be subject to agreement by the Naval Authority.

1.1.6 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.1.7 Where SOLAS requirements have been identified as a route to satisfying goals associated with objectives, these are for guidance purposes. Where there is no specific SOLAS guidance provided in the Rules, the designer can propose solutions to LR that embrace the recognised practices that are consistent with the overall SOLAS philosophy.

1.2 Background

1.2.1 These Rules provide a framework and methodology for demonstrating that levels of safety and pollution prevention are to a standard acceptable to the Naval Authority and LR. The application of these Rules is not to compromise the levels of safety afforded to naval ships through the application of current regulatory regimes and military practices. The Rules recognise military design, construction, installation, testing, trials and through life operation and take due account of the military function of naval ships. The Rules provide a series of optional class notations that can be assigned to designs complying with relevant Parts of the Rules.

1.2.2 This Part of the Rules has been developed from the relevant requirements of:

- International Convention Safety of Life At Sea which is in force on 1 July 2002 (SOLAS); and
- International Convention for the Prevention of Pollution from Ships 1973 (MARPOL) which is in force on 1 July 2002;

taking due consideration of military philosophy.

1.2.3 Military philosophy that addresses ship survivability and system degradation are two key areas that commonly affect the application of merchant ship statutory requirements and these have been recognised in the Chapters applicable to different Class notations.

1.2.4 Modern naval ships are commonly required to have multi-purpose roles and extensive operational capabilities and it is necessary to ensure that that equipment and arrangements on board do not compromise the roles for which the ship may be required to operate within.

1.2.5 The assessment of the acceptability of equipment and arrangements required by these Rules is to ensure that a single failure of equipment will not render the system inoperable. Where this cannot be achieved there is to be sufficient engineering evidence that the likelihood of failure occurring is extremely remote.

1.2.6 Levels of manning, personnel training and qualifications are not within the scope of these Rules, however these will be given consideration when an alternative design approval is sought.

1.3 Scope of application

1.3.1 For the purposes of demonstrating compliance with these Rules, two alternatives are available;

(a) **Certificate of Compliance**, which provides evidence that the arrangements on board meet the requirements in the relevant section of the Rules. This will be confirmed by appropriate design appraisal followed by inspection and testing at survey. Designs other than those prescribed by the Rules will be recorded for information purposes by way of an addition to the certificate as an Annex. Where a defect, blemish or anomaly is noted at survey, and is not considered to require remedial attention at that time, an Annex will be added to the certificate for information purposes.

(b) **Class Notation**, which indicates that the arrangements on board meet the requirements in the relevant sections of the Rules and that a periodic survey regime of the equipment and systems has been established for the lifetime of the ship. When at any survey it is found that any damage, defect or breakdown is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable Condition of Class is imposed. The condition of class will be assigned with a date by which the repair is to be completed. Deviations from design standards will be recorded for information purposes as an Annex in the classification records. Likewise where a defect, blemish or anomaly is noted at survey, and is not considered to require remedial attention at that time, an Annex will be included in the classification records for information purposes.

1.3.2 These Rules are not intended to apply to ships under construction or upkeep where additional personnel and equipment may be present on board the ship. In general the Rules are only intended to apply where the ship is under naval command.

1.4 Topics within this Part of the Rules

1.4.1 **EER** (Escape, emergency access, evacuation and rescue). This notation will be assigned to naval ships which demonstrate that the arrangements are in accordance with the requirements of these Rules or are to a standard which meets the Objectives specified in these Rules. For a ship to be eligible for **EER** notation, it is to be demonstrated that it is fully compliant with the requirements of Chapters 2, 3 and 4 of this Part of the Rules, i.e. **FIRE**, **ESC** and **LSAE** notations are to be capable of being assigned to the vessel. System integration is to be in accordance with Section 4 of this Chapter.

1.4.2 **FIRE** – Fire Protection. This notation will be assigned to naval ships which demonstrate that the provision of fire protection equipment and arrangements on board a vessel comply with the requirements of Chapter 2 of this Part of the Rules.

1.4.3 **ESC** – Escape and Emergency Access. This notation will be assigned to naval ships which demonstrate that the escape arrangements and emergency access on board comply with the requirements of Chapter 3 of this Part of the Rules.

1.4.4 **LSAE** – Life Saving and Evacuation Arrangements. This notation will be assigned to naval ships which demonstrate that the life saving, evacuation and rescue arrangements on board comply with the requirements of Chapter 4 of this Part of the Rules.

1.4.5 **SNC** – Safety of Navigation and Communication. This notation will be assigned to naval ships which demonstrate that the navigation and communication equipment on board comply with the requirements of Chapter 5 of this Part of the Rules.

1.4.6 **POL** – Pollution Prevention. This notation will be assigned to naval ships which demonstrate that the pollution prevention measures on board comply with the requirements of Chapter 6 of this Part of the Rules.

1.4.7 **Star Endorsements (★)**. All Class Notations that are available in this Part of the Rules will be eligible for a 'Star' endorsement where the arrangements on board are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

■ *Section 2* General information

2.1 Responsibilities

2.1.1 The **Naval Authority** is responsible for defining the regulations and requirements associated with the design, procurement, installation and support of equipment and systems within the scope of application of this Part of the Rules. *See* Vol 1, Pt 1, Ch 2,2.2.6 for definition of Naval Authority.

2.1.2 **Lloyd's Register** (Classification Society) is responsible for confirming and accepting that equipment and arrangements required by the applicable Rules and requirements associated with a particular class notation are satisfied. *See* Vol 1, Pt 1, Ch 2,1.3.1 regarding interpretation of the Rules.

2.1.3 The **National Administration** is responsible for confirming that the equipment and arrangements are acceptable to them for recognition of the requirements associated with a particular class notation with a star (★) endorsement, *see* 1.4.7.

2.1.4 The **Designer** is responsible for co-ordination of all matters relating to demonstrating compliance with the Rules and any requirements of the Naval Authority and National Administration.

2.1.5 The **Owner** has ultimate responsibility for ensuring a safety standard acceptable to the Naval Authority is being applied, *see also* Vol 1, Pt 1, Ch 2,1.4.

2.2 Appraisal and review

2.2.1 Prior to the formal appraisal process being commenced a concept statement is to be submitted and agreed with LR, *see* 2.3.2.

2.2.2 A design disclosure is to be submitted to LR for appraisal as required by the applicable parts of the Rules.

2.2.3 All systems are to be constructed and assembled from equipment suitable for its intended purpose and acceptable to the Naval Authority and/or the National Administration where a 'Star' endorsement is required. Such equipment will typically have a relevant Type Approval Certificate or an EC Marine Equipment Directive Certificate issued by LR or an organisation acceptable to LR. Equipment with other certification may be acceptable as an alternative subject to a satisfactory review by LR. Details will be noted as an Annex in the applicable certification or class documentation, *see* 1.3.1.

2.3 Plans and information

2.3.1 The ship's civil and military operational profile specifying the functionality and capability in defined operating and foreseeable failure conditions of the ship is to be submitted. This is to be agreed between the designer and Owner/Operator.

2.3.2 A Concept Statement detailing the capability and functionality of the system under consideration detailing defined civil and military operating and emergency conditions is to be submitted. The Concept Statement is to include but is not limited to:

(a) Required Certificates of Compliance or Class Notations.
(b) Description of the ship's operational capabilities, (Concept of Operations) to include any defined military survivability requirements.
(c) Details of the intended mode of operation of the equipment/system to include environmental conditions.
(d) Manning levels and operator competencies/authorisations required.
(e) Indication of whether or not alternative design assessment is being sought if the proposed design deviate from the specified guidance identified in these Rules.

2.3.3 In addition to the submission of an acceptable Concept Statement, a more detailed Design Disclosure is required for submission to and acceptance by LR. The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of safety and pollution prevention systems.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/ component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Evidence of compliance with the Objectives and Goals defined in the Chapter of the Rules applicable to that system. This may be in the form of compliance with any specified guidance/technical references, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see* Section 6.
(d) Details of the hazard identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure then details are to be submitted.
(e) Descriptions of designated places of safety and safe havens, etc., as required by the relevant Chapters of the Rules.
(f) Details of the proposed test procedures required to demonstrate functionality at the time of commissioning for all systems covered by these Rules.

The details of the Design Disclosure are subject to review and acceptance by LR. A letter of acceptance will be issued by LR after satisfactory review of the Design Disclosure.

2.3.4 Where a Naval Authority has approved equipment, systems and arrangements which are usually subject to these Rules for Classification purposes, full details are to be submitted to LR for information. Details are to include information on the equipment/arrangements, certification and test reports.

2.4 Inspection and survey

2.4.1 The requirements for inspection and survey are such that it is to be demonstrated to LR that the arrangements on board the ship are in accordance with the description within those detailed in the Design Disclosure.

2.4.2 Where a Class Notation is requested, a survey regime is to be established to ensure that the arrangements on board are maintained to an acceptable standard as long as the vessel is to be assigned a particular Class Notation. All surveyable items as accepted in the Design Disclosure are to included in the survey regime.

Section 3 **Definitions**

3.1 Safety equipment and arrangements

3.1.1 **Escape**. Movement of personnel to a designated place of safety on board. (This may be co-ordinated movement or the action of individuals. Since this is mainly concerned with the flow of personnel through the ship it may also be taken to include normal access.)

3.1.2 **Evacuation**. Movement of all personnel to a survival craft in case of an emergency.

3.1.3 **Rescue**. Process by which personnel are taken to an ultimate point of safety. (This definition does not include the ability to conduct Search and Rescue but covers the ability to locate and rescue personnel in an emergency. (Search is covered by the **SNC** notation, *see* Chapter 5).

3.1.4 **Ultimate point(s) of safety** is/are to be declared in the Design Disclosure, and can, amongst other things, be another vessel, aircraft or dry land.

3.1.5 **Designated place(s) of safety** is/are to be declared in the Design Disclosure. These are to be places on board the vessel which may be reasonably expected to be used as platforms for evacuation following escape.

3.1.6 **Emergency access** arrangements allowing for movement of personnel within the ship for the purposes of damage control and fire-fighting.

3.1.7 **Alternative design and arrangements** mean safety and pollution prevention measures which deviate from any prescriptive requirement(s) of these Rules, but are acceptable to LR to satisfy the objective(s) and the functional requirements of the relevant Chapter. The term includes a wide range of measures, including alternative shipboard structures and systems based on novel or unique designs, as well as traditional shipboard structures and systems that are installed in alternative arrangements or configurations. Depending on the nature and extent of the deviation, it will be accepted by way of either a Concession or Alternative Design Justification, *see* 6.1.4.

3.1.8 **Design hazard** means an engineering description of a hazard which is identified at the design stage.

3.1.9 **Design scenario** means a set of conditions and incidents which may reasonably be expected to occur during the life of a system. These conditions and incidences are to be used in identifying the design hazards.

3.1.10 **Functional requirements** explain, in general terms, what function the ship and shipboard systems/equipment must provide in order to meet the safety objectives of these Rules.

3.1.11 **Hazard identification** is the process whereby all hazards identified at the design stage are catalogued.

3.1.12 **Locating signals** are radio transmissions intended to facilitate the finding of a mobile unit in distress or the location of survivors. These signals include those transmitted by searching units, and those transmitted by the mobile unit in distress, by survival craft, by float-free EPIRBs (Emergency Position-Indicating Radio Beacons), by satellite EPIRBs and by search-and-rescue radar transponders to assist the researching units.

3.1.13 **Performance criteria** are measurable quantities stated in engineering terms to be used to judge the adequacy of trial designs.

3.1.14 Personnel:

(a) **Crew**. All personnel on board the ship for its operational role. This includes personnel for navigation and maintenance of the ship, its machinery and weapons/aircraft systems. Naval trainees on board for the purpose of training in naval operations identified in the previous sentence are also within the scope of the definition of crew.

(b) **Embarked personnel**. Additional personnel other than crew, embarked on the ship for a specific task or purpose or for military purposes. Such personnel may include additional specialised maintenance personnel for ship systems, technicians on trials during normal operation, aircraft crew, and military personnel on a mission which may be any naval related activity under naval command including trials, training, humanitarian aid and military activities.

(c) **Passengers** is every person other than the crew and embarked personnel.

3.1.15 **Safety margin** means adjustments made to allow for uncertainties in the methods and assumptions used to evaluate an alternative design (*see* 3.1.7), e.g. in the determination of performance criteria or in the engineering models used to assess the consequences of a hazard.

3.1.16 **Sensitivity analysis** means an analysis to determine the effect of changes in individual input parameters on the results of a given model or calculation method.

3.1.17 **Survival craft**. A survival craft is a craft capable of sustaining the lives of personnel in distress from the time of evacuating the ship. This may include supporting ships and aircraft.

3.1.18 **Gross tonnage (GT)** of a ship is to be determined for the purposes of these Rules, by the following formula:

$$GT = K_1 V$$

where

V = total volume of all enclosed spaces in the ship in cubic metres and includes gun turrets, radar domes, masts, etc.

K_1 = $0,2 + 0,02 \log_{10} V$

3.1.19 **Fire zones** are those sections into which the hull, superstructure and deckhouses are divided by fire resistant divisions. Fire resistant divisions are those which are installed and/or protected for the purpose of restricting the spread of fire.

■ *Section 4* Integration for EER notation

4.1 General

4.1.1 The **EER** notation will be assigned to ships which demonstrate compliance with all the requirements for **FIRE**, **ESC** and **LSAE** notations.

4.1.2 In addition to the requirements of 4.1.1 the systems and their arrangements are to be integrated in such a manner so as to support safe and effective task performance. The systems are to be integrated in accordance with the requirements of 4.2.

4.2 System integration

4.2.1 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure, agreed between the designer and the Owner/Operator.

4.2.2 The procedure is to identify the roles, responsibilities and requirements of all parties involved.

4.2.3 Safety systems are to be designed, as far as is practicable, so that their integration with other systems will not degrade the performance of any other system.

4.2.4 Where the integration involves control functions for essential services or safety functions, a robust system analysis procedure, such as a Failure Modes and Effects Analysis, is to be used to demonstrate that the integrated system will not render essential services inoperable as a result of single item failure.

■ *Section 5* Acceptance criteria

5.1 General

5.1.1 The acceptance criteria ensure conformity of safety and pollution prevention systems to the Provisions of Classification (*see* Vol 2, Pt 1, Ch 1,2) of LR's Rules and Regulations and specified Standards or Codes.

5.1.2 The route to conformance detailed in Section 6 provides details on the process for demonstrating that equipment and systems are acceptable to LR.

5.1.3 The acceptance criteria of safety and pollution prevention systems extend over the full lifecycle of the systems.

5.2 Design

5.2.1 The design of safety and pollution prevention systems is to be in accordance with these Rules.

5.3 Construction

5.3.1 Safety and pollution prevention systems, and their components are to be constructed in accordance with standards acceptable to LR and which satisfy the Rule requirements.

5.4 Installation/testing

5.4.1 Safety and pollution prevention systems are to be installed in accordance with plans appraised by LR and Rule requirements to the satisfaction of LR.

5.5 Trials

5.5.1 Safety and pollution prevention systems are to be tested in accordance with a procedure agreed between LR and the Designer.

5.6 Through life operations

5.6.1 Safety and pollution prevention systems are to be maintained through life such that the applicable Rule objectives and Provisions of Classification can be ascertained and found in a condition that is acceptable to LR.

5.7 Modifications

5.7.1 Details of all modifications to safety and pollution prevention systems and equipment are to be appraised and found acceptable to LR.

■ *Section 6* Route to conformance

6.1 Route to conformance

6.1.1 The Route to conformance in 6.1.3 provides the process for demonstrating that systems and equipment satisfy the acceptance criteria of Section 5.

6.1.2 Conformance with this Part of the Rules is recognised by LR through the assignment of an associated Class Notation or issuing of a Certificate of Compliance.

6.1.3 The route to conformance throughout the life cycle requires the following:

(a) **Design**. Plans are to be appraised by LR when required by the Rules and where a military distinction notation has been requested by the Owner.
(b) **Construction**. To be constructed under survey where required by the Rules.
(c) **Installation**. Systems are to be installed under survey in accordance with plans appraised by LR and with Rule Requirements.
(d) **Trials**. Systems are to be tested under normal working conditions.

(e) **In Service**. Systems will be subject to survey where required by the Rules or Regulations or where requested by Owners or Naval Authority.

(f) **Modification**. Details of any modifications are to be appraised and construction, installation and trials are to be carried out under survey when required by the Rules for a Class notation.

(g) **Decommissioning**. Details are to be submitted for information.

6.1.4 At each stage in the process there may be occasions where the prescriptive requirements cannot be met. Where the reasons for non-compliance have a military justification, conformance is to be managed through one of the following:

(a) **Concession**. A concession may be granted at the discretion of an authorised LR Surveyor. The concession is only granted where the Surveyor considers the deviation not to effect the overall design philosophy of the Rules. The concession will be recorded in the Annex to the Certificate of Compliance or Classification Records as applicable.

(b) **Alternative design justification**. An alternative design justification report is required to be developed in accordance with the Naval Survey Guidance where the LR Surveyor considers the deviation to be of a critical or significant nature to be assessed on judgement alone. Following a satisfactory review of the report, LR will issue a letter of acceptance. The letter of acceptance and principal details from the report will be recorded in the Annex to the Certificate of Compliance or Classification records as applicable.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that the arrangements on board a naval ship prevent fire occurring and reduce the consequences of damage to the ship or personnel arising from fire.

1.1.2 The Objectives of this Chapter as defined in 4.2 are to be realised through the contents of these Rules that aim to prevent the occurrence of fire and ensure any fire will be detected, located, extinguished and contained in its space of origin.

1.1.3 In general, demonstration of satisfactory levels of fire protection will be achieved through compliance with the relevant requirements of these Rules and the documents referenced therein. Where fire protection arrangements deviate from the specified guidance/technical references of this Chapter they are to be capable of satisfying the functional requirements and fire safety objectives and goals of this Chapter.

1.1.4 This Chapter of the Rules is to be read in conjunction with Chapter 1.

1.2 Application

1.2.1 The requirements in this Chapter of the Rules are applicable where a Certificate of Compliance or a Class Notation for Fire Protection, **FIRE**, is requested.

1.2.2 The ‘Star endorsement’ (★) will be assigned to vessels where the arrangements onboard are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

■ *Section 2* Classification requirements for fire protection systems

2.1 General requirements

2.1.1 The Fire Protection **FIRE** notation will be assigned to naval vessels which are shown to have levels of fire protection in accordance with these Rules.

2.1.2 It is a prerequisite of the **FIRE** notation that an **LMC** notation, or equivalent, has been assigned to the vessel, *see* Ch 1,1.1.2.

■ *Section 3* Plans and particulars

3.1 Concept statement

3.1.1 The design intent of any fire protection system is to be submitted in the form of a Concept Statement and is to include but not limited to:

(a) The required class notation, **FIRE** or **FIRE★**. If a military distinction (**MD**) notation is required this is also to be declared, *see* Vol 1, Pt 1, Ch 2,3.7.

(b) A Concept of Operations which is a description of the ship’s designed operational role and capabilities and is to include any defined military survivability requirements.

(c) Details of the intended mode of operation of the fire protection systems/equipment to include environmental conditions together with a description of any fire scenarios and their development and application in the design

(d) Manning levels, drills, exercises and operator competencies/authorisations required.

(e) Indication of whether or not alternative design assessment is being sought, if the proposed design deviate from the specified guidance identified in these Rules.

The concept statement is to be agreed by the designer and Owner/Operator, *see also* Ch 1,2.3.2.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable Concept Statement, a Design Disclosure is required for submission to and acceptance by Lloyd's Register (hereinafter referred to as 'LR'). The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of fire protection systems.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Details of the proposed survey and maintenance regime.
(d) Evidence of compliance with the Objectives and Goals defined in Sections 5 to 12. This may be in the form of compliance with specified guidance/technical references, Concessions, Alternative Design Justification Reports or an acceptable combination of all three. *See also* Ch 1,2.3 and 6.
(e) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted.
(f) Details of equipment configurations that are safe for operators and users.
(g) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.
(h) Details of system interaction, *see* Section 10.

3.3 Plans

3.3.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements, for inspection installation and testing, guidance on the plans and details to be submitted for assessment and review are detailed in 3.3.2 and 3.3.4.

3.3.2 For fire safety arrangements, the following plans and information:

(a) A statement of the method of structural fire protection adopted and prevention of fire spread.
(b) A general arrangement plan showing main fire zones, escape routes and the fire compartmentalisation bulkheads and decks within main fire zones, including the machinery spaces, magazine spaces, equipment spaces, vehicle and aircraft spaces, accommodation areas, galleys, paint stores, inflammable substance stores, navigating bridge, weapon/aircraft operating/control rooms, store rooms, fuel tanks, fire-fighting control room and emergency generators. The plan should also include location of fire command and control stations. Where fire parties are utilised, the location of each control station in each fire zone is to be indicated.
(c) A plan showing the details of construction of the fire protection bulkheads and decks and the particulars of any surface laminates employed.
(d) Copies of certificates of any approval in respect of fire divisions, non-combustible materials and materials having low flame spread properties, etc., which are to be used but have not been approved by LR.
(e) A plan showing the construction and operation of fire doors.
(f) A ventilation plan showing ducts, any smoke extractor facilities and any dampers in them, and the position of controls for operation.
(g) A plan showing the location and arrangement of the emergency stop for flammable oil unit pumps and for closing the valves on pipes from flammable oil tanks.
(h) An arrangement plan of the fire alarms if applicable.

3.3.3 For fire-extinguishing arrangements, the following plans and information:

(a) A general arrangement plan showing the location of all the fire-fighting equipment including the fire extinguishing water system, the fixed fire-extinguishing systems in magazines, vehicle and aircraft spaces, on deck and in the machinery spaces; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the fire-fighters' outfits.
(b) A plan showing the layout and construction of the fire extinguishing water system, including all the designated fire pumps, isolating valves, pipe sizes and materials, the international shore connections and the cross connections to any other systems.
(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.
(d) A plan showing any sprinkler and/or detection equipment locations, as applicable.
(e) Details of fire parties and availability of fire-fighters' outfits.

3.3.4 A fire control plan that is to be permanently exhibited for the guidance of the ship's crew, showing clearly for each deck the control stations, the various fire sections together with particulars of the fire detection and alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc., the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating plans serving each station.

■ *Section 4* General requirements

4.1 The Rules

4.1.1 The Rule requirements are arranged in terms of eight fundamental objectives which all contribute to the overall performance of the fire protection arrangements, *see* 4.2.1(a) to (h).

4.1.2 Each of the eight objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal, or series of goals, is detailed; the goals are then developed as performance requirements; and ultimately the specified guidance/technical references.

4.1.3 In general, a system is to be compliant with the SOLAS convention, however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced SOLAS Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level as those in SOLAS.

4.2 Fire protection objectives

4.2.1 The fire protection objectives to be satisfied by all fire protection systems are as follows;

(a) **Fire Prevention Objective**. Every ship is to be designed and equipped so as to prevent the occurrence of fire or explosion, taking due account of its civil and military operational role, *see* Section 5.
(b) **Fire Detection Objective**. Every ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion, *see* Section 6.
(c) **Fire Extinguishing Objective**. Every ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished, *see* Section 7.
(d) **Containment Objective**. Every ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin, *see* Section 8.
(e) **Personnel Hazard Objective**. All reasonable measures are to be taken to prevent hazards to personnel as a result of fire, *see* Section 9.
(f) **System Interaction Objective**. The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable, *see* Section 10.
(g) **Command and Control Objective**. Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated, *see* Section 11.
(h) **Structural Integrity Objective**. Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat, *see* Section 12.

■ *Section 5* Fire prevention

5.1 Fire prevention objective

5.1.1 Every ship is to be designed and equipped so as to prevent the occurrence of fire or explosion, taking due account of its civil and military operational role. The Fire Prevention Goals described in 5.1.2 to 5.1.6 may be achieved by the application of Referenced SOLAS Regulations which are for guidance purposes. *See also* 4.1.3.

5.1.2 **Fire Prevention Goal 1**. Sources of ignition within the ship are to be kept to a number that is as low as reasonably practicable.

(a) In general, arrangements for items of ignition sources and ignitability are to be in accordance with SOLAS Chapter II-2, Part B, Regulation 4.4.

5.1.3 **Fire Prevention Goal 2**. The use of combustible and potentially explosive materials is to be restricted and controlled, taking due cognisance of the locality of ignition sources.

(a) Arrangements for oil fuel, lubrication oil and other flammable oils are to be in accordance with SOLAS Chapter II-2, Part B, Regulation 4.2.
(b) Arrangements for gaseous fuel for domestic purposes are to be in accordance with SOLAS Chapter II-2, Part B, Regulation 4.3.

5.1.4 **Fire Prevention Goal 3**. The fire hazards associated with helicopter facilities are to be as low as reasonably practicable:

(a) In general the arrangements for helicopter facilities are to be in accordance with SOLAS Ch II-2, Regulation 18.

5.1.5 **Fire Prevention Goal 4**. The fire hazards associated with the carriage of dangerous goods are to be as low as reasonably practicable:

(a) In general the arrangements for the carriage of dangerous goods are to be in accordance with SOLAS Ch II-2, Regulation 19.

5.1.6 **Fire Prevention Goal 5**. The fire hazards associated with the carriage of vehicles, special category and ro-ro spaces are to be as low as reasonably practicable:

(a) In general the arrangements for the carriage of vehicles, special category and ro-ro spaces are to be in accordance with SOLAS Ch II-2, Regulation 20.

■ *Section 6* Fire detection

6.1 Fire detection objective

6.1.1 Every ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion. The Fire Detection Goal described in 6.1.2 may be achieved by the application of the referenced SOLAS Regulations which are for guidance purposes. *See also* 4.1.3.

6.1.2 **Fire Detection Goal 1**. Every ship is to be equipped with effective heat/flame and smoke detection systems that will function correctly in the environment in which a fire may be reasonably expected to occur.

(a) In general the arrangements for detection and alarm are to be in accordance with SOLAS Chapter II-2, Part C, Regulation 7.2.
(b) The testing of fixed fire detection and alarm systems are to be in accordance with SOLAS Chapter II-2, Part C Regulation 7.3.
(c) The protection of machinery spaces is to be in accordance with SOLAS Chapter II-2, Part C, Regulation 7.4.
(d) The protection of accommodation, service spaces and control stations is to be in accordance with SOLAS Chapter II-2, Part C, Regulation 7.5.
(e) The provision of manually operated call points is to be in accordance with SOLAS Chapter II-2, Part C, Regulation 7.7.
(f) Fire patrols are to be arranged in accordance with SOLAS Chapter II-2, Part C, Regulation 7.8.
(g) Fire-alarm signalling is to be in accordance with SOLAS Chapter II-2, Part C, Regulation 7.9.

6.1.3 **Fire Detection Goal 2**. Systems are to be arranged so as to detect the re-ignition of a detected and extinguished fire.

■ *Section 7* Fire extinction

7.1 Fire extinguishing objective

7.1.1 Every ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished. The Fire Extinguishing Goals described in 7.1.2 and 7.1.3 my be achieved by the application of the referenced SOLAS Regulations and the technical references which are for guidance purposes. *See also* 4.1.3.

7.1.2 **Fire Extinguishing Goal 1**. Arrangements on board are to be such that all detected fires can be extinguished using a media which is suitable for the nature of the fire.

(a) Unless given otherwise in the following paragraphs, arrangements for the extinction of fire are to be in accordance with SOLAS Chapter II-2 Part C, Regulation 10.
(b) Where high pressure sea-water systems are used for fire-fighting purposes, they are to be in accordance with the requirements of Vol 2, Pt 7, Ch 5,10.
(c) The water fire-fighting system is to have a capacity, equal to the requirements of HPSW systems as outlined in Vol 2, Pt 7, Ch 5,10.2.3.
(d) The number and position of hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship where a fire can be reasonably expected. Such hydrant is to be located near the access to protected spaces. Hydrants for boundary cooling for the expected fire scenarios are also to be made available.
(e) With regard to pressure at hydrants, the water fire-fighting system is to be capable of delivering the required quantity of water at adjacent hydrants with the following pressures being available at all hydrants:
    - 4 bar for NS1 and NS2 ships and all ships of 4000 gross tonnage or greater.
    - 3 bar for NS3 ships.

    The pressure is not to exceed that for which the system has been designed, or that which the fire hose cannot be demonstrated as being controllable.
(f) With regard to the provision of fire pumps, ships of 4000 gross tonnage and above are to be fitted with at least three fire pumps, and ships of less than 4000 gross tonnage are to be fitted with at least two. If the pumps are arranged such that a single fire will put all pumps out of action, an additional emergency fire pump will be required.
(g) With regard to the requirements for fire hoses, at least one fire hose of the required length is to be permanently available at each required hydrant. These are to be for the sole use of fire-fighting and testing the equipment.
(h) With regard to sprinkler systems, NS1 and NS2 ships, and those designed to carry in excess of 50 embarked personnel, are to be fitted with an automatic sprinkler, fire detection and fire alarm system of a type acceptable to the Naval Authority in all control stations, accommodation and service spaces. Alternatively if a water sprinkler system may cause damage to essential equipment, a fixed fire-fighting system acceptable to the Naval Authority is to be used. Spaces where there is little or no risk of fire need not be fitted with such a system.
(j) On NS3 ships and vessels designed to carry less than 50 embarked personnel an automatic sprinkler, fire detection and fire alarm system of a type acceptable to the Naval Authority is to be installed to protect control stations. A fixed fire detection system and alarm is to be arranged to provide smoke detection in corridors, stairways, escape and access routes within accommodation spaces.
(k) With regard to fire-fighters' outfits, the fire-fighters' outfit is to be to a standard acceptable to the Naval Authority. As a minimum they are to be in accordance with the Fire Safety Systems Code (FSS Code).

(l) Each ship is to carry sufficient fire-fighters' outfits for the number required for each fire party as agreed with the Naval Authority. Each ship is to carry at least two fire-fighters' outfits. Two fire-fighters' outfits are to be provided for every 80 m of longitudinal deck space and in addition, two in every vertical zone. One water fog applicator is to be stored adjacent to each set of breathing apparatus. The fire-fighters' outfits and fog applicators are to be readily accessible in each fire zone.

(m) Where water is used for fire-fighting purposes in any compartment, these compartments are to be provided with arrangements for removing the water after fire extinguishing.

7.1.3 **Fire Extinguishing Goal 2**. The capacity of the extinguishing system is to be sufficient to extinguish any fire which may reasonably be expected to occur within the jurisdiction of that extinguishing system:

(a) With regard to the availability of water, at least one effective jet of water is to be immediately available from any hydrant in an interior space. The continued supply of that water is to be ensured by the automatic starting of a fire pump.

■ *Section 8* Fire and by-product containment

8.1 Fire and by-product containment objective

8.1.1 Every ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin. The Fire and By-Product Containment Goal in 8.1.2 my be achieved by the application of the Referenced SOLAS regulations and the technical references which are provided for guidance purposes. *See also* 4.1.3.

8.1.2 **Fire and By-product Containment Goal 1**. Adequate containment boundaries are to be fitted within the ship in order that spread of fire, smoke and toxic by-products is limited to a predetermined area, consistent with allowing as near normal operation of the vessel as practically possible in the event of fire, without evacuation.

(a) Arrangements for the containment of fire are to be in accordance with SOLAS Chapter II-2, Part C, Regulation 9.

(b) Control of air supply and flammable liquid to the space is to be in accordance with SOLAS Chapter II-2, Regulations Part B, 5.2. and Pt C, 8.2.

(c) With regard to closing devices, vessels designed to carry in excess of 50 embarked personnel, power ventilation, except in machinery spaces and control stations not having an exit to an open deck, is to be fitted with controls so that all fans can be stopped from either of two positions which should be located as far apart from each other as is practicable.

(d) All controls for the fire-extinguishing system shall be situated in one control position or in as few positions as possible to the satisfaction of the Naval Authority.

(e) The use of fire protection materials is to be in accordance with SOLAS Chapter II-2, Part B, Regulation 5.3.

(f) The arrangements for the control of smoke spread are to be in accordance with SOLAS Chapter II-2 Part C, Regulation 8.

■ *Section 9* Personnel fire hazards

9.1 Personnel hazard objective

9.1.1 All reasonable measures are to be taken to prevent hazards to personnel as a result of fire. The Personnel Hazard Goals in 9.1.2 and 9.1.3 may be achieved by the application of the referenced SOLAS Regulations which are provided for guidance purposes. *See also* 4.1.3.

9.1.2 **Personnel Hazard Goal 1**. Where materials used or carried may develop vapours and smoke dangerous to personnel, the ship is to be arranged so as to minimise the effects from those vapours and smoke.

(a) The potential for smoke generation and its toxicity is to be in accordance with SOLAS Chapter 2, Part B, Regulation 6.

9.1.3 **Personnel Hazard Goal 2**. Where personnel may be reasonably expected to fight a fire, there is to be adequate provision of protective equipment for each member of the fire-fighting party. The equipment is to be of a standard applicable for its intended application.

(a) Fire-fighters' outfits are to be in accordance with SOLAS Chapter II-2, Part C, Regulation 10.10, *see* 7.1.2 (j) and (k).

■ *Section 10* System interaction

10.1 System interaction objective

10.1.1 The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable.

10.1.2 **System Interaction Goal**. Systems are to be designed, as far as is practicable, to ensure that the operation of that system will not inadvertently degrade the performance of any other system.

■ *Section 11* Command and control

11.1 Command and control objective

11.1.1 Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated.

11.1.2 **Command and Control Goal 1**. Fire control stations are to be provided so that there can be a central point of command in all fire situations where fire-fighting may be expected.

11.1.3 **Command and Control Goal 2**. Fixed means of two-way speech communication are to be provided between the fire-fighting control station and identified fire risk areas.

■ *Section 12* Structural integrity

12.1 Structural integrity objective

12.1.1 Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat. The Structural Integrity Goal in 12.1.2 my be achieved by the application of the referred SOLAS Regulation which is provided for guidance purposes. *See also* 4.1.3.

12.1.2 **Structural Integrity Goal**. Materials used in the construction of the ship's structure are to ensure that structural integrity is not degraded due to fire.

(a) The arrangements for structural integrity following fire are to be in accordance with SOLAS Chapter II-2, Part C, Regulation 11. *See also* Vol 1, Pt 4, Ch 1,4.2.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship's crew and embarked personnel can escape from any space within the ship to a designated place of safety in a safe, timely and effective manner as the need arises. It also provides a method for confirming that access to essential areas is available for personnel and equipment required for damage control and fire fighting purposes.

1.1.2 The Objectives of this Chapter as defined in 4.2 are to be realised through the content of these Rules that aim to ensure the provision of sufficient equipment and arrangements to enable the removal of all personnel to a designated place of safety until such a time that they can be evacuated from the ship and to ensure adequate emergency access.

1.1.3 In general, demonstration of satisfactory escape arrangements will be achieved through compliance with the relevant requirements of SOLAS Chapter II-2, Regulation 13. Where escape arrangements deviate from the technical requirements of SOLAS they are to be suitable to satisfy the functional requirements, escape objective and goals of this Chapter.

1.1.4 Demonstration of acceptable emergency access arrangements will be achieved by satisfactory demonstration of the emergency access objective and associated goal.

1.1.5 This Chapter of the Rules is to be read in conjunction with Chapter 1 of the Rules for Naval Ships.

1.1.6 *See also* Chapter 4 of this Part of the Rules.

1.2 Application

1.2.1 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Escape and Emergency Access **ESC** is requested.

1.2.2 The 'Star endorsement' (★) will be assigned to vessels where the arrangements onboard are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

■ *Section 2* Classification requirements for escape and emergency access

2.1 General requirements

2.1.1 The Escape and Emergency Access **ESC** notation will be assigned to vessels which can demonstrate that the levels of personnel safety in the event of a 'prepare to evacuate' scenario are in accordance with these Rules.

2.1.2 Where the **ESC** notation is to be assigned, an **LMC** notation must have been assigned, *see* Ch 1,1.1.2

■ *Section 3* Plans and particulars

3.1 Concept statement

3.1.1 The design intent of any escape and emergency access arrangements is to be submitted in the form of a Concept Statement and is to include, but not be limited to;

(a) The required class notation, **ESC** or **ESC★**. If a military distinction (MD) notation is required this is also to be declared, *see* Vol 1, Pt 1, Ch 2,3.7.
(b) A Concept of Operations which is a description of the ship's operational capabilities and is to include any defined military survivability requirements.
(c) Details of the intended mode of operation of escape and emergency access systems/equipment to include environmental conditions together with a description of any escape and emergency access scenarios and their development and application in the design
(d) Manning levels and operator competencies/authorisations required.
(e) Indication of whether or not alternative design assessment is being sought, if the proposed design deviate from the specified guidance identified in these Rules.

The concept statement is to be agreed by the designer and Owner/Operator, *see also* Ch 1,2.3.2.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable Concept Statement, a Design Disclosure is required for submission to and acceptance by LR. The Design Disclosure is to include, but is not limited to:
(a) A description of the escape regime, i.e. estimated times to designated places of safety in all foreseeable conditions. This is also to include a declaration of all designated places of safety.
(b) A statement of all design standards used in the design, manufacture, installation and testing of escape and emergency access systems.
(c) A proposed list of all surveyable items together with any additional recommendations from equipment/ component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(d) Details of the proposed survey and maintenance regime.
(e) Evidence of compliance with the Objectives and Goals defined in Sections 5 and 6. This may be in the form of compliance with any specified guidance, Concessions, Alternative Design Justification Reports or an acceptable combination of all three. *See also* Ch 1,2.3 and 6.
(f) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted
(g) Details of equipment configurations that are safe for operators and users.
(h) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

See also Ch 1,2.3 and 6.

3.3 Plans

3.3.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements, for inspection, installation and testing; guidance on the plans and information to be submitted for assessment and review are detailed in 3.3.2 to 3.3.4.

3.3.2 For escape equipment, the following plans and information:
(a) Certificates of conformity.
(b) General arrangement plans of equipment, detailing all essential parameters, weights, safe working loads, etc.

3.3.3 For arrangements of equipment, the following plans and information:
(a) General arrangement plans of equipment layout, showing place of safety points, equipment stowage points, escape and access routes etc.

3.3.4 For deployment and operational procedures, the following information:
(a) Details of the deployment and operation of equipment.

■ *Section 4*
General requirements

4.1 The Rules

4.1.1 The Rule requirements are arranged in terms of two fundamental objectives which both contribute to the overall performance of the escape and emergency access arrangements, *see* 4.2.

4.1.2 Each of the two objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that an objective is stated as the highest level requirement. At the next level, a goal, or series of goals, are detailed; the goals are then developed as performance requirements; and ultimately specified guidance where applicable.

4.1.3 In general, a system is to be compliant with the SOLAS convention, however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced SOLAS Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level as those in SOLAS.

4.1.4 The escape routes are to be designed so as to support escape of all personnel to a designated place of safety. Where a pre-determined time for escape is specified in the Design Disclosure, based on the design and operational role of the ship then it is to be validated by full-scale trials or by a simulation acceptable to LR. This time is to be specified by the Naval Authority based on the design and operational role of the ship. The time is to be validated by full-scale trials or by a simulation acceptable to the Naval Authority and LR. *See also* the *Naval Survey Guidance*.

4.2 Escape of personnel and emergency access arrangements objectives

4.2.1 The escape and emergency access arrangements objectives to be satisfied by all escape and emergency access systems and arrangements are as follows;
(a) **Escape of Personnel Objective**. Every ship is to be arranged so that all spaces have means of safe and effective escape for personnel to a designated place of safety, during anticipated emergency situations, *see* Section 5.
(b) **Emergency Access Objective**. Every ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises, *see* Section 6.

Section 5 Escape of personnel

5.1 Escape objective

5.1.1 Every ship is to be arranged so that all spaces have a means of safe and effective escape for personnel to a designated place of safety, during anticipated emergency situations. The Escape Goals described in 5.1.2 to 5.1.7 may be achieved by the application of the referenced SOLAS Regulations which are for guidance purposes. *See also* 4.1.3.

5.1.2 **Escape Goal 1**. All escape routes are to provide for effective and obvious access to designated places of safety.

(a) In general the provision of escape routes on all ships is to be in accordance with SOLAS Chapter II-2, Regulations 13.1 to 13.4.

(b) In general escape routes from machinery spaces on all ships are to be in accordance with SOLAS Chapter II-2, Regulation 13.4.

(c) In general escape route arrangements for ro-ro spaces are to be in accordance with SOLAS Chapter II-2, Regulations 13.5 to 13.7.

5.1.3 **Escape Goal 2**. All escape routes are to be readily accessible.

5.1.4 **Escape Goal 3**. All escape routes are to be free from undue hazards.

5.1.5 **Escape Goal 4**. Physical dimensions of escape routes are to be suitable for the anticipated flow of personnel during all foreseeable emergency conditions.

(a) In general the dimensions and design of escape routes are to be in accordance with SOLAS Chapter II-2, Regulation 13.

5.1.6 **Escape Goal 5**. Personnel are to be adequately protected from fire, smoke and hazardous vapours while escaping.

5.1.7 **Escape Goal 6**. The escape arrangements for individual compartments are to be suitable for the purpose of the compartment and its intended occupants.

Section 6 Emergency access

6.1 Emergency access objective

6.1.1 Every ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises.

6.1.2 **Emergency Access Goal 1**. Provisions for emergency access are to be arranged such that they do not contribute to the spread of fire, flood, smoke or other toxic gases to the designated places of safety.

Life-Saving and Evacuation Arrangements

Section

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship can be evacuated in a safe and effective manner as the need arises, and that personnel can be effectively rescued from the water.

1.1.2 The objectives of this Chapter as defined in 4.2 are to be achieved through the content of these Rules that aim to ensure the provision of sufficient equipment to evacuate all personnel to a place of safety until such a time that they can be rescued, and to ensure that adequate equipment is provided to rescue personnel from the water.

1.1.3 In general, demonstration of adequate provision of life-saving and rescue equipment will be achieved through compliance with the relevant requirements of SOLAS Chapter III. Where life-saving and rescue arrangements deviate from the requirements of SOLAS Chapter III they are to be suitable to satisfy the life saving and rescue objectives and functional requirements of this Chapter.

1.1.4 This Chapter of the Rules is to be read in conjunction with Chapter 1.

1.2 Application

1.2.1 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Life-Saving and Evacuation Arrangements **LSAE** is requested.

1.2.2 The 'Star endorsement' (★) will be assigned to vessels where the arrangements onboard are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

■ *Section 2* Requirements for life-saving and evacuation arrangements

2.1 General requirements

2.1.1 The Life-Saving and Evacuation Arrangements **LSAE** notation will be assigned to vessels which demonstrate that the provision of life-saving and rescue equipment on board are in accordance with these Rules.

2.1.2 Where the **LSAE** notation is to be assigned, an **LMC** notation must have been assigned, *see* Ch 1,1.1.2

■ *Section 3* Plans and particulars

3.1 Concept statement

3.1.1 The design intent of any life saving or rescue system is to be submitted in the form of a Concept Statement and is to include, but not be limited to;

(a) The required class notation, **LSAE** or **LSAE★**. If a military distinction (**MD**) notation is required this is to be declared, *see* Vol 1, Pt 1, Ch 2,3.7.
(b) A Concept of Operations which is a description of the ship's designed operational role and capabilities and is to include any defined military survivability requirements.
(c) Details of the intended mode of operation of life-saving and evacuation systems/equipment to include environmental conditions together with a description of any emergency scenarios and their development and application in the design.
(d) Manning levels and Operator competencies/authorisations required.
(e) Indication of whether or not alternative design assessment is being sought, if the proposed design deviate from the specified guidance identified in these Rules.

The Concept Statement is to be agreed by the designer and Owner/Operator, *see also* Ch 1,2.3.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable Concept Statement, a Design Disclosure is required for submission to and acceptance by Lloyd's Register (hereinafter referred to as 'LR'). The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of life-saving and rescue equipment.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Details of the proposed survey and maintenance regime.

(d) Evidence of compliance with the Objectives and Goals defined in Sections 5 to 8. This may be in the form of compliance with specified guidance, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see also* Ch 1,2.3 and 6.
(e) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted.
(f) Details of equipment configurations that are safe for Operators and users.
(g) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

3.3 Plans

3.3.1 To support the design disclosure and for the purposes of assessing compliance with design requirements for inspection, installation and testing; guidance on the plans and information to be submitted for assessment and review are detailed in 3.3.2 to 3.3.4.

3.3.2 For life-saving appliances, the following plans and information:
(a) Certificates of conformity against the International Life Saving Appliance Code (MSC Res. 48(66)) or other standard acceptable to the Naval Authority and Lloyd's Register.
(b) General arrangement plans of equipment, detailing all essential parameters, weights, Safe Working Loads, etc.

3.3.3 For arrangements of equipment, the following plans :
(a) General arrangement plans of equipment layout, showing embarkation points, equipment stowage points, etc.
(b) General arrangement plans of all equipment assemblies such as davits, reeving arrangements, etc.

3.3.4 For operational procedures, the following information:
(a) Details of the evacuation procedure, to include drills and training.
(b) An evacuation analysis in accordance with SOLAS Chapter II-2, Regulation 13,7.4.

■ *Section 4* General requirements

4.1 The Rules

4.1.1 The requirements are arranged in terms of four fundamental objectives which all contribute to the overall performance of the life-saving and evacuation arrangements, *see* 4.2.

4.1.2 Each of the four objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal or series of goals, are detailed; the goals are then developed as performance requirements; and ultimately specified guidance were applicable.

4.1.3 In general, a system is to be compliant with the SOLAS convention, however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced SOLAS Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level as those in SOLAS.

4.1.4 These Rules are based on the requirements of SOLAS Chapter III and all terms and definitions are referenced therein. All references to the Code refer to the International Life-Saving Appliance Code.

4.1.5 The evacuation systems are to be designed so as to support evacuation of all personnel in a pre-determined time. This time is to be agreed by the Naval Authority based on the design and operational role of the ship. The time is to be validated by full-scale trials or by a simulation acceptable to the Naval Authority and LR. *See also* the *Naval Survey Guidance*.

4.2 Life-saving and evacuation arrangements objectives

4.2.1 The objectives to be satisfied by all life-saving and evacuation systems are as follows:
(a) **Evacuation Objective**. Arrangements are to be provided to enable personnel to evacuate the ship safely and in a time acceptable to the Naval Authority, *see* Section 5.
(b) **Personnel Protection Objective**. Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft, *see* Section 6.
(c) **Rescue Objective**. Every ship is to be suitably equipped to rescue personnel from the water, *see* Section 7.
(d) **Command and Control Objective**. Every ship is to be equipped and manned so that command of all evacuation and life-saving situations can be maintained, *see* Section 8.

Section 5
Evacuation of personnel

5.1 Evacuation objective

5.1.1 Arrangements are to be provided to enable personnel to evacuate the ship safely and in a time acceptable to the Naval Authority. The Evacuation Goals described in 5.1.2 to 5.1.6 my be achieved by the application of the referred SOLAS Regulations and technical references which are for guidance purposes. *See also* 4.1.3.

5.1.2 **Evacuation Goal 1**. Life-saving equipment is to be arranged on the vessel in such a manner that it is easily accessible and readily deployed in the case of an emergency.

(a) In general, the provision of life jackets is to be in accordance with SOLAS Chapter III, Part B, Regulation 7.2.

(b) Arrangements for life-saving and evacuation equipment are to be in accordance with SOLAS Chapter III, Part B, Regulations 11, 12, 13, 15 and 16 as applicable.

(c) Arrangements for operational readiness are to be in accordance with SOLAS, Part B, Chapter III, Regulation 20.

5.1.3 **Evacuation Goal 2**. The total capacity of the ships survival craft is to be sufficient to ensure that all personnel can be evacuated during foreseeable emergency conditions:

(a) The provision of survival craft and rescue boats is to be in accordance with SOLAS Part B, Chapter III, Regulation 31.

5.1.4 **Evacuation Goal 3**. All life-saving and rescue equipment is to be of an approved type acceptable to LR, the Naval Authority and National Administration where applicable:

(a) In general, all life-saving and rescue equipment prototypes are to be tested to confirm that they comply with the International Life Saving Appliance Code or other standard acceptable to Lloyd's Register and the Naval Authority.

(b) All life-saving and rescue equipment is to be subject to production tests to ensure that they are constructed to the same standard as the approved prototype.

5.1.5 **Evacuation Goal 4**. Provision is to be made to ensure that the deployed survival craft can be moved to safety from a damaged vessel until such time all personnel can be rescued.

5.1.6 **Evacuation Goal 5**. Provision is to be made for incapacitated people to be evacuated to safety.

Section 6
Personnel protection

6.1 Personnel protection objective

6.1.1 Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft. The Personnel Protection Goal described in 6.1.2 my be achieved by the application of the referenced SOLAS Regulation which is for guidance purposes. *See also* 4.1.3.

6.1.2 **Personnel Protection Goal 1.** Evacuated personnel are to be protected from the adverse effects of the environment such as hypothermia or exposure:

(a) In general, the provision of immersion suits and anti-exposure suits is to be consistent with SOLAS Chapter III, Part B, Regulation 7.3.

6.1.3 **Personnel Protection Goal 2.** Survival craft are to be equipped with sufficient provisions to keep personnel free from starvation and dehydration for a period of time specified by the Naval Authority.

Section 7
Rescue of personnel

7.1 Rescue of personnel objective

7.1.1 Every ship and its life saving equipment are to be suitably equipped to locate and rescue personnel from the water. The rescue of Personnel Goals described in 7.1.2 to 7.1.4 may be achieved by the application of the referenced SOLAS Regulations which are for guidance purposes. *See also* 4.1.3.

7.1.2 **Rescue of Personnel Goal 1**. Every ship is to be designed to prevent the risk of an accidental man overboard situation as far as is practicable:

(a) Line throwing appliances are to be in accordance with SOLAS Part B, Chapter III, Regulation 18.

(b) In general, the provision of life buoys on all ships is to be in accordance with SOLAS Chapter III, Part B, Regulation 7.1. With regard to the marking of life buoys, all life buoys are to be marked with the ships' identification number.

7.1.3 **Rescue of Personnel Goal 2**. Every ship is to be suitably equipped for the mass rescue of personnel from the water, on board:

(a) Rescue boat launching and recovery arrangements are to be in accordance with SOLAS Part B, Chapter III, Regulation 17.

(b) Rescue boats are to be stowed in accordance with SOLAS, Part B, Chapter III, Regulation 14.

7.1.4 **Rescue of Personnel Goal 3**. Every ship and its survival craft are to be fitted with equipment to ensure that the ship and its survival craft can be efficiently located and retrieved as necessary.

(a) Each ship is to be fitted with at least one radar transponder on both sides. The radar transponders are to be located such that they can be readily deployed on any survival craft, other than the life rafts.

(b) The provision of flares is to be in accordance with SOLAS Chapter III, Part B, Regulation 6.3.

■ *Section 8* Command and control

8.1 Command and control objective

8.1.1 Suitable means are to be provided to ensure that life-saving and evacuation operations can be safely and effectively orchestrated. The Command and Control Goals described in 8.1.2 may be achieved by the application of the referenced SOLAS Regulations which are for guidance purposes. *See also* 4.1.3.

8.1.2 **Command and Control Goal 1**. Every ship is to be equipped and manned so that command of all life-saving and evacuation situations can be maintained:

(a) Every ship is to be fitted with a general emergency alarm in accordance with SOLAS Chapter III, Part B, Regulation 6.4.4 as applicable. The alarm is to be audible on all open decks and every compartment.

(b) Every ship is to be fitted with a public address system in accordance with SOLAS Chapter III, Part B, Regulation 6.5.

(c) Emergency situation instructions are to be in accordance with SOLAS Chapter III, Part B, Regulations 8 and 9.

(d) The manning and supervision of life saving appliances are to be in accordance with SOLAS Chapter III, Part B, Regulation 10.

(e) Emergency and training drills are to be in accordance with SOLAS Part B, Chapter III, Regulation 19.

8.1.3 **Command and Control Goal 2.** Reliable means of speech communication are to be provided between the central point of command and strategic life-saving and evacuation stations:

(a) Two-way VHF radiotelephone apparatus is to be provided on every ship.

Safety of Navigation and Communication

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that the arrangements on board a naval ship provide for navigation and communication equipment and arrangements which provide for safe and effective task performance and to meet the requirements of international regulations.

1.1.2 The objectives of this Chapter as defined in 4.2 are to be realised through the content of these Rules that detail the functional requirements that are to be met by the ship's navigation and communication systems.

1.1.3 In general, demonstration of satisfactory levels of safety of navigation and communication will be achieved through compliance with the relevant requirements of these Rules and the documents referenced therein. Where navigation and communication arrangements deviate from the technical requirements of this chapter they are to be suitable to satisfy the objectives of and goals of this Chapter.

1.1.4 In addition to the requirements for ships to be furnished with the necessary equipment for effective navigation and communication, SOLAS requires the contracting Governments to provide certain shore-based facilities and services. These services assist the ships in maintaining effective navigation and communication. It is beyond the scope of these Rules to mandate that the Navies Government is to provide such services, however it must be noted that they are an essential part of the ship's operation.

1.1.5 The requirements placed on the contracting Governments can be found in SOLAS Chapter IV Part B and Chapter V Regulations 4 to 14 inclusive, and Regulation 31.

1.2 Application

1.2.1 The requirements of this Chapter are to be read in conjunction with Chapter 1.

1.2.2 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Safety of Navigation and Communication (**SNC**) is requested.

1.2.3 The 'Star' ★ endorsement will be assigned to vessels where the arrangement on board are acceptable to the National Administration for regulating safety of navigation and communications requirements for a particular ship.

■ *Section 2* Classification requirements for safety of navigation and communication systems

2.1 General requirements

2.1.1 The Safety of Navigation and Communication **SNC** notation will be assigned to vessels that demonstrate that the levels of navigation and communication are in accordance with these Rules.

2.1.2 No provision in these Rules is to prevent the use by any ship, survival craft or person in distress, of any means at their disposal to attract attention, make known their position and obtain help.

2.1.3 The Requirements of this Chapter are based on those of SOLAS Chapters IV and V, and the terms and definitions referenced therein are to be referred to.

2.1.4 Where the **SNC** notation is to be assigned, an **LMC** notation must have been assigned, *see* Ch 1,1.1.2.

■ *Section 3* Plans and particulars

3.1 Design statement

3.1.1 The design intent of the communication and navigation arrangements is to be submitted and is to include all necessary supporting information with:

(a) the required class notation;
(b) details of the operational profile of the ship, to include manning provisions and training levels; and
(c) a description of each mode of operation of the systems in each identifiable operational state.

3.2 Engineering and safety justification

3.2.1 The design intent of any communications and navigation system is to be submitted in the form of a Concept Statement and is to include but not be limited to:

(a) The required class notation, **SNC** or **SNC★**. If a military distinction (**MD**) notation is required this is also to be declared. *See* Volume 1, Pt 1, Ch 2,3.7.
(b) Description of the ship's operational capabilities, (Concept of Operations) to include any defined military survivability requirements.
(c) Details of the intended mode of operation of navigation and communication systems/equipment to include environmental conditions, to include a description of any emergency scenarios and their development and application in the design
(d) Manning levels and Operator competencies/authorisations required.
(e) Indication of whether or not alternative design assessment is being sought, if the proposed design deviate from the specified guidance identified in these Rules.

The concept statement is to be agreed by the designer and Owner/Operator, *see also* Ch 1,2.3.2.

3.3 Plans

3.3.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements for inspection, installation and testing; guidance on the plans and details to be submitted for assessment review are detailed in 3.3.2 and 3.3.3.

3.3.2 For navigation, the following information:

(a) Schematic plan of ship-wide navigation systems.
(b) Detailed description of navigation systems operation.

3.3.3 For communication, the following information:

(a) Schematic plan of ship-wide communication systems.
(b) Detailed description of communication systems operation.

■ *Section 4* General requirements

4.1 The Rules

4.1.1 The requirements are arranged in terms of four fundamental objectives which all contribute to the overall performance of safety of navigation and communications arrangements, *see* 4.2.

4.1.2 Each of these four objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal or series of goals, are detailed; the goals are then developed as performance requirement; and ultimately specified guidance.

4.1.3 In general, a system is to be compliant with the SOLAS convention, however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced SOLAS Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level as those in SOLAS.

4.2 Safety of navigation and communications objectives

4.2.1 The safety of navigation and communications objectives to be satisfied by all ships is as follows:

(a) **Communication Objective**. Every ship is to be capable of communication to avert unnecessary danger to itself and other ships in the vicinity during normal and emergency conditions, *see* Section 5.
(b) **Safety of Navigation Objective**. Every ship is to be arranged with the necessary equipment to facilitate safe and effective navigation, *see* Section 6.
(c) **Equipment Arrangements Objective**. All navigation and communications equipment is to be arranged to allow safe and effective task performance, *see* Section 7.

■ *Section 5* Safety of communication

5.1 Communication objective

5.1.1 Every ship is to be capable of communication to avert unnecessary danger to itself and other ships in its vicinity. The Communication Goal in 5.1.8 may be achieved by the application of the referenced SOLAS Regulation which is provided for guidance purposes. *See also* 4.1.3.

5.1.2 **Communication Goal 1**. Every ship is to be capable of transmitting ship-to-shore distress alerts during all normal operation and foreseeable failure conditions.

5.1.3 **Communication Goal 2**. Every ship is to be capable of receiving shore-to-ship distress alerts during all normal operating conditions.

5.1.4 **Communication Goal 3**. Every ship is to be capable of transmitting and receiving ship-to-ship distress alerts during all normal operating conditions.

5.1.5 **Communication Goal 4**. Every ship is to be capable of transmitting and receiving search and rescue co-ordinating communications during all normal operating conditions.

5.1.6 **Communication Goal 5**. Every ship is to be capable of receiving on-scene communications during normal operating conditions.

5.1.7 **Communication Goal 6**. Every ship is to be capable of transmitting and receiving signals for the purposes of locating mobile units and individuals in distress.

5.1.8 **Communication Goal 7**. Every ship is to be capable of transmitting and receiving maritime safety information during normal operating conditions:

(a) In general the requirements of SOLAS Chapter V, Regulation 32 and 33 are to be applied.

5.1.9 **Communication Goal 8**. Every ship is to be capable of transmitting and receiving general radio-communications to and from shore-based radio systems or networks where available.

■ *Section 6* Safety of navigation

6.1 Navigation objective

6.1.1 Every ship is to be arranged with the necessary equipment to facilitate safe and effective navigation. The Navigation Goals described in 6.1.2, 6.1.5, 6.1.6, 6.1.7 and 6.1.8 may be achieved by the application of the referenced SOLAS Regulations which are provided for guidance purposes. *See also* 4.1.3.

6.1.2 **Navigation Goal 1**. Each ship is to be fitted with a means for the helmsman to determine ship track and heading at the normal place of steering during normal operating and foreseeable failure conditions:

(a) In general, the requirements of SOLAS Chapter V, Regulations 24 and 25 are to be complied with.

6.1.3 **Navigation Goal 2**. There is to be adequate means of communication between any ship control and navigating stations.

6.1.4 **Navigation Goal 3**. There is to be a means of taking bearings as nearly as practicable over the arc of the horizon of 360°.

6.1.5 **Navigation Goal 4**. The ship's steering gear is to be tested in accordance with SOLAS Chapter V, Regulation 26 as applicable.

6.1.6 **Navigation Goal 5**. Where the ship is likely to use a pilot to navigate certain waterways, then arrangements on board are to be sufficient to safely embark and disembark the pilot:

(a) In general, the requirements of SOLAS Chapter V, Regulation 23 are to be complied with.

6.1.7 **Navigation Goal 6**. Every ship is to be equipped with all necessary publications to facilitate safe navigation:

(a) The requirements of SOLAS Chapter V, Regulations 27, 28, 30 and 34 are to be applied as necessary.

6.1.8 **Navigation Goal 7**. Each ship is to be provided with requirements for shipborne navigational systems and equipment:

(a) The requirements of SOLAS Chapter V, Regulations 19 and 20 are to be applied as applicable.

■ *Section 7* Safety of navigating and communication equipment arrangements

7.1 Equipment arrangements objective

7.1.1 All navigation and communications equipment is to be arranged to allow safe and effective task performance. The Equipment Arrangements Goals described in 7.1.2, 7.1.3, 7.1.5 and 7.1.6 may be achieved by the application of the referred SOLAS regulations which are provided for guidance purposes. *See also* 4.1.3.

7.1.2 **Equipment Arrangements Goal 1**. The navigational bridge is to be arranged to allow clear visibility of all equipment needed for navigation purposes:

(a) In general, the requirements of SOLAS Chapter V Regulation 22 are to be complied with.

7.1.3 **Equipment Arrangements Goal 2**. All navigating and communications equipment is to be located to avoid interference that affects its proper use and so as to ensure electromagnetic compatibility and avoidance of harmful interaction with other equipment and systems:

(a) In general, the requirements of SOLAS Chapter V, Regulation 17 are to be complied with.

7.1.4 **Equipment Arrangements Goal 3**. All navigating and communications equipment is to be located to avoid the harmful effects of water, extremes of temperature and other environmental conditions.

7.1.5 **Equipment Arrangements Goal 4**. All navigation and communications equipment is to be arranged so as it remains functional in all foreseeable failure conditions:

(a) In general, all communication equipment is to be in accordance with the requirements of SOLAS Chapter IV, Part C, Regulations 6, 15, 16 and 17.

(b) In general, the bridge is to be arranged in accordance with SOLAS Chapter V, Regulation 15.

7.1.6 **Equipment Arrangements Goal 5**. All navigation equipment is to be maintained to ensure that it remains in an efficient working order:

(a) In general equipment is to be maintained in accordance with SOLAS Chapter V, Regulation 16.

Section

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship meets the applicable requirements of the International Maritime Organisation's MARPOL Convention.

1.1.2 This Chapter details the Regulations of MARPOL applicable to naval ships for the purposes of these Rules, and details how these are to be complied with.

1.2 Application

1.2.1 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Pollution Prevention (**POL**) is requested.

1.2.2 The requirements of these Rules are to be satisfied as part of the **EP** notation included in Vol. 3, Pt 2, Ch2.

■ *Section 2* Requirements for pollution prevention arrangements

2.1 General requirements

2.1.1 The Pollution Prevention Notation **POL** notation will be assigned to vessels that demonstrate that the provision equipment and procedures on board are in accordance with the requirements of Section 4 of these Rules.

2.1.2 In addition Certificates of Compliance will be provided where the arrangements are found in accordance with Section 5 of these Rules. (The MARPOL requirements detailed in Section 5 have not been ratified at IMO to date.)

2.1.3 Where the **POL** notation is to be assigned, an **LMC** notation must have been assigned, *see* Ch 1,1.1.2.

■ *Section 3* Plans and particulars

3.1 Design statement

3.1.1 The design intent of any pollution prevention system required by the regulations is to be submitted and is to include all necessary supporting information with:
(a) The required class notation, **POL**, or Certificate of Compliance to MARPOL Annex IV or VI. If a military distinction notation is required this is also to be declared.
(b) Details of the operational profile of the ship, to include manning provisions and training levels.
(c) A description of each mode of operation of the systems in each identifiable potential pollution of the sea or air scenarios.

The design statement is to be agreed by the designer and Owner/Operator.

3.2 Design declaration

3.2.1 In addition to submission of an acceptable Concept Statement, a Design Disclosure is required for submission to and acceptance by Lloyd's Register. The Design Disclosure is to include, but is not limited to:
(a) a statement of all design standards used in the design, manufacture, installation and testing of pollution prevention equipment and systems;
(b) a proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates;
(c) details of the proposed survey and maintenance regime;
(d) evidence of compliance with the Objectives and Goals defined in Sections 4 and 5. This may be in the form of compliance with prescriptive Rules, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see also* Ch 1,2.3 and Ch 1,6;
(e) details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure then details are to be submitted;
(f) details of equipment configurations that are safe for operators and users;
(g) details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

3.3 Plans

3.3.1 To support the engineering and safety justification and for the purposes of assessing compliance with design requirements, for inspection installation and testing; guidance on the plans and information to be submitted for assessment and reviews are detailed in 3.3.2 to 3.3.4.

3.3.2 For pollution prevention equipment, the following plans and information:
(a) Certificates of conformity against MARPOL Annexes as required by these Rules.
(b) General arrangement plans of equipment, detailing all essential parameters, capacity, flow rates, etc.

3.3.3 For arrangements of equipment the following plans and information:
(a) General arrangement plans of equipment layout, showing tanks, discharges, etc.
(b) General arrangement plans of all equipment assemblies such as oily water separators, pumps, etc.

3.3.4 For procedures, the following information:
(a) Details of the pollution prevention procedure, to include oil record books, sewage discharge, etc.

■ *Section 4*
Prevention of pollution by oil and garbage

4.1 Applicable Regulations of MARPOL Annex I (Oil Pollution)

4.1.1 The following Regulations and associated requirements are applicable to naval ships:
(a) Regulation 9, The control and discharge of oil.
(b) Regulation 10, Methods of prevention of oil pollution from ships while operating in special areas.
(c) Regulation 14, Segregation of oil and water ballast and carriage of oil in forepeak tanks.
(d) Regulation 16, Oil discharge monitoring and control system and oil filtering equipment.
(e) Regulation 17, Tanks for oil residues (sludge).
(f) Regulation 19, Standard discharge connection.
(g) Regulation 20, Oil record book.
(h) Regulation 26, Shipboard oil pollution emergency plan.

4.2 Applicable Regulations of MARPOL Annex V (Garbage Pollution)

4.2.1 All regulations of MARPOL Annex V are to be complied with.

■ *Section 5*
Prevention of pollution by sewage and pollution of the air from ships

5.1 Regulations of MARPOL Annex IV (Sewage Pollution)

5.1.1 Where required by the Naval Authority, all regulations of MARPOL Annex IV are to be complied with. This Annex is yet to be ratified at IMO.

5.2 Regulations of MARPOL Annex VI (Pollution of the Air)

5.2.1 All relevant regulations of MARPOL Annex VI are to be complied with.

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